Chapter 1

Compiling single sections at a time

For writing purposes only.

1.1 Background

1.1.1 Early universe

After the big bang, all space and matter existed as a near singular point of near infinite density and temperature (although temperature is hard to define at such scales). At this point all particles exist in a hot soup of fundamental particles, leptons, quarks, and force-carriers. add table 30.2 and reference to Carroll&Ostlie?

As the universe expands, the temperature and density decreases. Inflation

Formation of baryons/mesons

Recombination -¿ neutral universe -¿ CMB

Primordial matter

(reference to Caroll and Ostlie?)

Gravitational collapse

The formation of stars and galaxies

Galaxies

Stars

1.1.2 Nuclear physics of stars

The nucleus

Write about the modern models for the nucleus

Interaction of nuclei

nuclear physics, nuclear physics experiments, cross-sections, density and temperature dependence

Production of heavy elements

Write about the neutron capture processes Make a new section here where I describe the application to stars and chemical production burbridge paper?

1.1.3 Galactic chemical evolution

Start by piecing together the tiniest of nuclear physics with the galactic and stellar physics Typical history of chemical enrichment as a galaxy ages Write about models for chemical evolution, both one-zone and others

More subsections about GCE

Omega

Eris

1.1.4 Cosmic clocks

I should probably start here!

$^{187}_{75}$Re is a long-lived radioactive nucleide with a half-life of $\simeq$ 40Gyr (site source for half-life). This means that, given an cosmic abundance of $^{187}_{75}$Re, half of the $^{187}_{75}$Re-nuclei will β^--decay to $^{187}_{76}$Os. In such a radioactive process, $^{187}_{75}$Re is called the parent-nuclide, while $^{187}_{76}$Os is called the daughter-nuclide. Since this relation between parent and daughter is exponential in time, the age of the parent can be calculated from the amount of parent-nuclei and daughter-nuclei that decay from parent.

$$
\begin{aligned}
A_x(t) &= A_x(t_0)e^{-\lambda_x t} && \beta^-\text{-decay of radioactive nuclei} \\
\frac{A_x(t)}{A_x(t_0)} &= e^{-\lambda_x t} \\
\frac{1}{2} &= e^{-\lambda_X \tau_{1/2}} && \text{insert definition of half-life } \tau_{1/2} \\
\lambda_x &= \frac{-\ln\frac{1}{2}}{\tau_{1/2}} = \frac{\ln 2}{\tau_{1/2}} \\
A_x(t) &= A_x(t_0)e^{-\frac{\ln 2}{\tau_{1/2}}t}
\end{aligned}
$$

$add description of variables$

Radioactive isotope dating with C-14 etc.

A well known example of radioactive dating is the β^--decay from $^{14}_{6}$C to $^{14}_{7}$N. The $\tau_{1/2}$ of $^{14}_{6}$C is (insert value and citation here), and this isotope is created in the atmosphere from cosmic rays (insert citation here). In the atmosphere there will always be a fraction of $^{14}_{6}$C proportional to $^{14}_{7}$N and cosmic ray irradiation. For a few multiples of the carbon-14-halflife(roughly how many years?), $^{14}_{7}$N and cosmic ray irradiation can be assumed to be constant. Since all living animals/plants eventually get their "daily dose" of carbon from the air(either by breathing or eating things that breathe), all living animals/plants consist of equal abundance of $^{14}_{6}$C relative to the neutral counterpart $^{12}_{6}$C. However this exchange of matter stops as the animal/plant in question dies and the metabolism stops, then the $^{14}_{6}$C abundance will β^--decay with a halflife of ($\tau_{1/2}$ = insert halflife here). If the skeleton is well kept, the amount of $^{14}_{6}$C can be measured and compared to the present day amount. Using the simple exponential equation in (add reference to equations) the time of death can be calculated from the halflife and relative amount of radioactive parent:

$$t_0 = -\frac{\tau_{1/2}}{\ln 2} \ln \frac{A_{^{14}_{6}\mathrm{C}}(t_{\mathrm{now}})}{A_{^{14}_{6}\mathrm{C}}(t_0)}$$

add description of variables

Radioactive isotope dating on r-process elements

Generally how to about the whole shit

1.2 The 'Omega' model

OMEGA stands for 'One-zone Model of the Evolution of Galaxies' and evolves the isotopic content of a galaxy. The model is a one-zone model, which means that the entire galaxy is simplified to a single point. A zero-space-dimensional galaxy model seems unrealistic, but it can be imagined as the mean value for a three-space-dimensional galaxy model. Add reference to cote-paper

1.2.1 process

1.2.2 Relevant parameters

`'Omega'` has many input parameters, both numerical and physical in nature[1], to guide the evolution of the galaxy.

This section will describe the most relevant ones.

[1] A physical input parameters are model parameters, while a numerical parameter decides on which calculations to choose from and where to get data. E.g initial gas of

galaxy This string option chooses predefined parameters to best match a certain galaxy on record. The relevant options are:

None No parameters determined.

milky_way_cte Set present dark matter mass to $10^{12}M_\odot$ and present stellar mass to $5 \times 10^{10}M_\odot$, and use a constant star formation rate of $1\frac{M_\odot}{yr}$

milky_way Set present dark matter mass to $10^{12}M_\odot$ and present stellar mass to $5 \times 10^{10}M_\odot$, and use the star formation rate from Chiappini et al. (2001) add proper reference

dt Length of first timestep (in yrs)

special_timesteps Number of logarithmic timesteps

tend Final point in time (in yrs)

mgal Initial mass of gas (if not calculated by other means), defaults to $10^{10}M_\odot$

imf_type Which form to use for the initial mass function explain this somewhere .

sfh_array Two one-dimensional arrays, time and star formation rate, that `'Omega'`will interpolate over in order to find the star formation rate at a given time.

in_out_control Boolean switch to turn on or off inflow and outflow.

inflow_rate Constant inflow rate in $\frac{M_\odot}{yr}$. Gas with primordial composition (reference to BBN?) flows into the galaxy.

outflow_rate remove this? Constant outflow rate in $\frac{M_\odot}{yr}$. Enriched gas from the interstellar medium is removed from the galaxy.

mass_loading Fraction of solar masses ejected per solar mass created as star. A different way of calculating outflow based on star formation rate.

out_follows_E_rate Adds a time-delay to outflow with mass_loading such that outflow follows supernova rate.

transitionmass=8 Mass-limit that separates the AGB stars from the massive stars explain these stars somewhere . Defaults to $8M_\odot$

galaxy is considered physical, while the boolean switch to turn on neutron star mergers are considered numerical.

popIII_on Boolean switch that turn on or off the use of Population III stars

pop3_table Yield tables for population III stars

imf_bdys_pop3 The boundaries of the initial mass function of population III stars.

sn1a_on Boolean switch that turn on or off the use of type 1a supernovae.

nb_1a_per_m The number of type 1a supernovae per solar mass formed. Used to calculate the number of type 1a supernovae from star formation rate.

sn1a_table Yield table for type 1a supernovae

sn1a_rate This string option chooses which distribution to calculate the rate of type 1a supernovaefrom. Options are powerlaw, gaussian, and exponential distribution.

- **beta_pow** Set the power of the power law distribution if 'sn1a_rate' is "power_law"
- **gauss_dtd** Set the mean and standard deviation of the gaussian distribution if 'sn1a_rate' is "gauss"
- **exp_dtd** Set the e-folding time of the exponential distribution if 'sn1a_rate' is "exp"

ns_merger_on Boolean switch to turn on or off binary neutron star mergers

bhns_merger_on Boolean switch to turn on or off black hole neutron star mergers

nsmerger_table Yield table of binary neutron star mergers

nb_nsm_per_m Set the number of neutron star mergers per solar mass formed as stars.

t_nsm_coal Set the time after which all neutron stars collide/merge

nsm_dtd_power Set the powerlaw distribution of the neutron star merger delay-time distribution explain this somewhere .

f_merger Fraction of binary systems that eventually merge. All systems are considered binary. This is instead of 'nb_nsm_per_m'

m_ej_nsm solar masses ejected per neutron star merger.

1.3 Fitting of models

In order to have the one-zone model `'Omega'` best reproduce the `'Eris'` simulation
... continue introduction and description
Some parameters are decidedly locked from the `'Eris'` simulation directly. One of the most valuable result from `'Eris'` (for these purposes) are the star formation rate thorugh Galactic time (also known as star formation history). The Galctic age in `'Eris'` is 14Gyr. In order to produce stars, a mass function has to be set. A mass function is the statistical probability distribution of mass for a population of stars. In `'Eris'` the Kroupa94 (insert reference here)
(insert image of distribution here?) mass function is used, and the same shall also be used for `'Omega'`. The stellar synthesis in `'Eris'` postproduction comes from core collapse supernova, type 1a supernova and binary neutron star mergers. In the appropriate `'Omega'` the black hole - neutron star mergers shall not be taken into effect, and the yield table for binary neutron star mergers is chosen to be insert reference to Arnould add comment/description about how the yield table is the r-process from the sun , because it contains $^{187}_{75}$Re.

define new commands for MWOmega/MWCteOmega/fiducccial model

introduce 'our' `'Omega'` model as the concept *'fiduccial model'*

1.3.1 Inserting parameters directly

describe parameters: sfr, tend, imf, BNSM/BHNSM, yield-tables etc. fix stellar mass plot data The first step towards finding an appropriate parameter space for `'Omega'` is to make `'Omega'` follow the stellar evolution of `'Eris'`. This is achieved by setting the initial mass function to Kroupa93 (insert reference) , and the star formation history from the `'Eris'` simulation. By activating type 1a supernovae and binary neutron star mergers, the stellar evolution of `'Omega'` should be similar in nature to `'Eris'`. In the star formation history of `'Eris'`, the endtime is 14Gyr, and the endtime for `'Omega'`should be set to the same value. There is only one(out of two) available yield tables for binary neutron star mergers that contain output for $^{187}_{75}$Re, in the interest of this project we naturally choose this one (add reference to yield tables) .

The main issue for all models is clear: star formation uses up all the gas in the model and star formation is quenched.

do I skip the spectroscopic plots?

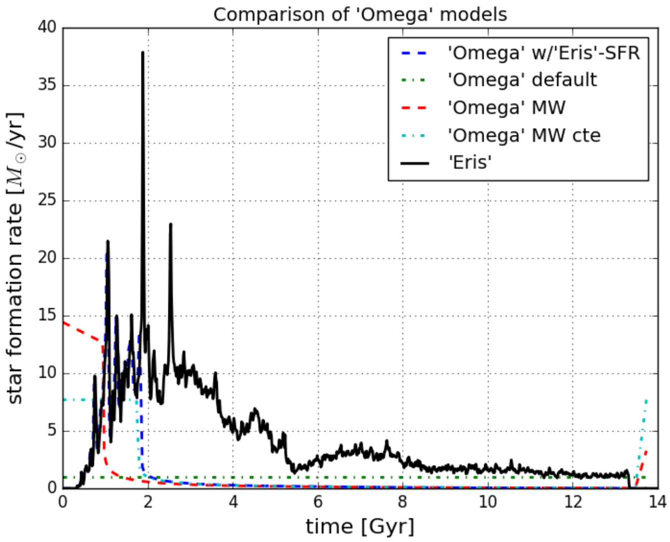


Figure 1.1: Star formation rate(measured in solar masses of stars formed from gas each year) for four models of `'Omega'` versus time. *'Eris'* refers to data directly from `'Eris'`-simulation. *'Omega' default* refers to the `'Omega'` model with no change to the initial parameters (see description in section **??**). *'Omega' MW* refers to the `'Omega'` model with the Milky Way parameter (see description in section **??**), and *'Omega' MW cte* refers to the same but with a constant one-solar-mass-per-year star formation rate. *'Omega' w/'Eris'-SFR* refers to the `'Omega'` model with the star formation and mass function from `'Eris'`. Firstly it is clear that star-formation is suppressed for all models except *'Omega' default*. This is from the lack of gas to create stars from. Secondly the *'Omega' w/'Eris'-SFR* model is the only model to accurately reproduce the `'Eris'` star formation at early times. While both *'Omega' MW* and *'Omega' MW cte* are meant to represent the milky way, they cannot be used to accurately represent `'Eris'`.

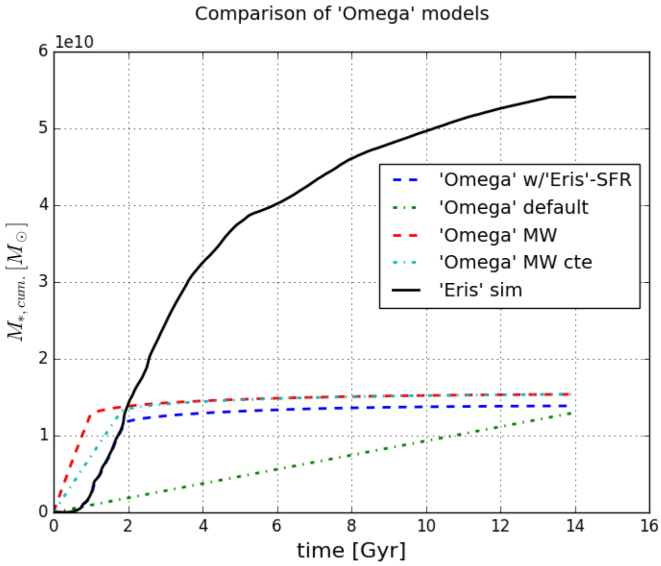


Figure 1.2: Total accumulated stellar mass(cumulutaive sum of stellar mass produces from gas, measured in solar masses) for four models of `'Omega'` versus time. *'Eris'* refers to data directly from `'Eris'`-simulation. *'Omega' default* refers to the `'Omega'` model with no change to the initial parameters (see description in section **??**). *'Omega' MW* refers to the `'Omega'` model with the Milky Way parameter (see description in section **??**), and *'Omega' MW cte* refers to the same but with a constant one-solar-mass-per-year star formation rate. *'Omega' w/'Eris'-SFR* refers to the `'Omega'` model with the star formation and mass function from `'Eris'`. This graph also shows that stellar production is suppressed at early time from lack of gas. Small amount of stars are still created from the enriched gas expelled by dying stars at late times, however this is a small contribution to the stellar production. Only *'Omega' w/'Eris'-SFR* can accurately reproduce *'Eris'* at early times, unlike the other `'Omega'` models.

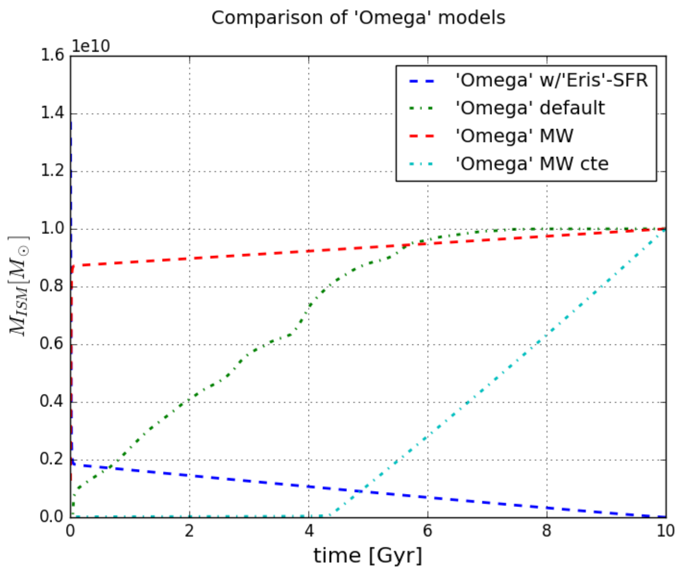


Figure 1.3: Mass of gas in the interstellar medium for four different models of `'Omega'`, and the `'Eris'` simulation against time in Gyrs. *'Eris'* refers to data directly from `'Eris'`-simulation. *'Omega' default* refers to the `'Omega'` model with no change to the initial parameters (see description in section **??**). *'Omega' MW* refers to the `'Omega'` model with the Milky Way parameter (see description in section **??**), and *'Omega' MW cte* refers to the same but with a constant one-solar-mass-per-year star formation rate. *'Omega' w/'Eris'-SFR* refers to the `'Omega'` model with the star formation and mass function from `'Eris'`. The gas, that is the foundation for star formation, is used up before 2 Gyrs for all models except for *'Omega' default*.

1.3.2 Modifying masses

what are realistic masses, outflows, inflows? explain next step of process

In order to produce enough stars to reproduce `'Eris'` the galaxy-model must have more gas. The `'Omega'` supports inflow of primordial gas from the medium around the galaxy, and outflow of chemically enriched gas into the surrounding medium. However, since `'Omega'`is a *one-zone* model, the chemically enriched material cannot return from the surrounding medium. That would require a two-zone model (or reater). A constant rate will be used for inflow, while a outflow rate proportional to the supernova rate will be used to create a more realistic model within the restrictions og `'Omega'`.

f_b []	z[]	$M_{vir}[10^{11}M_{\odot}]$	$M_b[10^{10}M_{\odot}]$	t[Gyr]
0.121	0.0	7.9	9.6	13.724
0.126	1.0	5.4	6.8	6.075

Table 1.1: From Guedes10 table 1 , f_b is the baryonic mass fraction of the galaxy, z is the redshift in the simulation, M_{vir} is the virial mass of the halo, M_b is the total baryonic mass within the halo(multiplication of f_b and M_{vir}), t is the time of the corresopnding redshift. Time is calculated from redshift using Ned Wright's cosmology calculator(February 12th 2018) reference to cosmology calculator article here with the cosmological parameters, $H_0 = 73[kms^{-1}Mpc^{-1}]$, $\Omega_M = 0.24$, and $\Omega_\Lambda = 1 - \Omega_M = 0.76$ for a flat universe as stated in reference guedes10-article .

From table ?? the total baryonic content of the galaxy is known at redshift zero and one. This information is used to fix the initial mass of primordial gas and inflow of primordial gas.

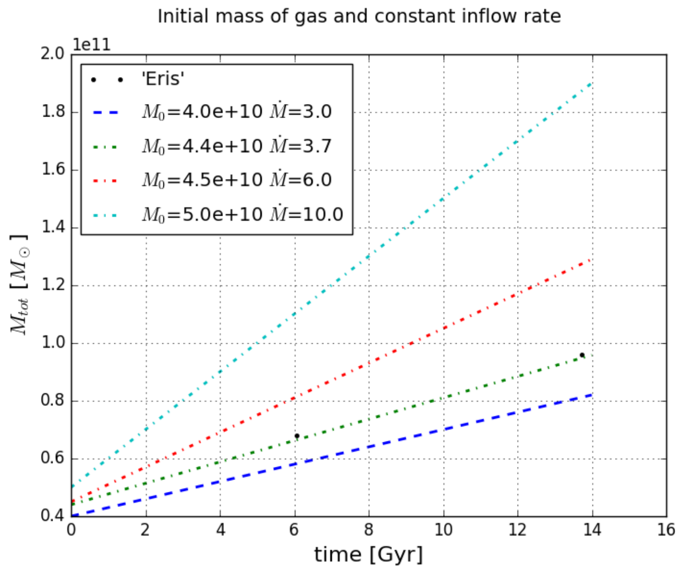


Figure 1.4: The total baryonic mass of the `'Omega'`-model for four different initial/inflow parameters. M_0 is the initial primordial gas of the galaxy(in $M_\odot$), $\dot{M}$ is the inflow (in $M_\odot$ /yr). This visualization shows that 44G $M_\odot$ and 3.7 $M_\odot$ /yr are the optimal parameters to reproduce the two baryonic data-points from `'Eris'`, although more then these four were tried.

Supernova feedback will drive an outflow from the galaxy into the surrounding medium find appropriate reference . Adding outflow proportional to the supernova rate adds some realisim to the model, and might reproduce some of the spectroscopic features. In `'Omega'`this is activated with the parameters `mass_loading`(which ejects a amount of gas relative to the stellar mass formed), and `out_follows_E_rate`(which adds a timedelay to the outflow, making the outflow proportional to the supernova rate instead of the star formation rate). Outflow removes gas from the galaxy, or interstellar medium, lowering the total amount of mass in the galaxy. Therefor the initial primordial gas and constant inflow must be increased as well.

add spectroscopic outflow plot here!

Setting the initial mass, inflow and outflow, gives the desired star formation. A final comparison of the fiducial `'Omega'`model, the predefined models (, , and `'Omega'`with all default parameters), and the data from the `'Eris'` simulation. For the predefined models, the initial mass of primordial gas have been increased to $9.6 \times 10^{10} M_\odot$(the final value baryon-mass

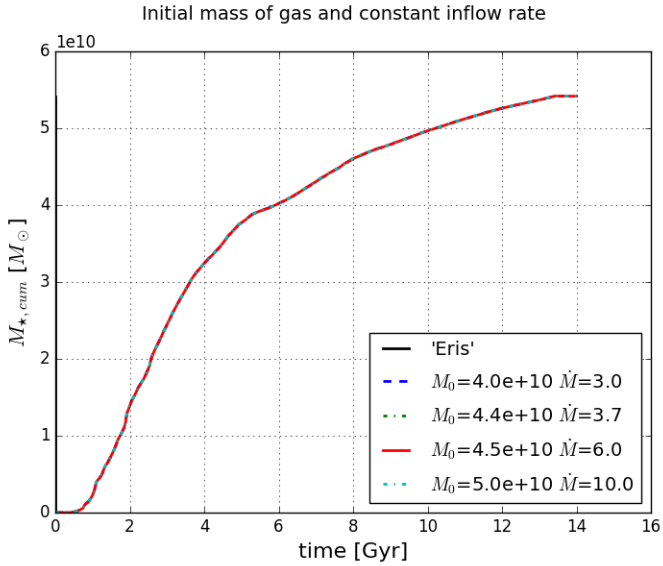


Figure 1.5: Plotting the cumulative stellar mass formed in the inflow-`'Omega'`-models. All four reproduce the `'Eris'` cumulative star formation, because these models have enough gas to form the stars.

from `'Eris'`) to show the full evolution of star formation. Two prominent features in the spectroscopic data of `'Eris'` is the two 'dips' around universal time t=5 and t=8 Gyrs. These dips might be reproduced by adding primordial inflow, hydrogen, and enriched outflow, concentrated on on those periods($t \simeq 5Gyr$ and $t \simeq 8Gyr$), since these periods might coincide with the death of stars from the star forming peak in figure **??**. Varying supernova-related outflow(known as the `mass_loading` parameter) gives an expected result. In figure **??** variation in the spectroscopic iron abundance can be seen the desired region, around the two 'dips', but the effect is too small to reproduce the two dips. The effect is also too wide and more closely similar to one big 'dip'. One unexpected result is that the smalles `mass_loading` parameter yields the lowest dip(not really a dip at all, but more flat in the desired direction). suggesting that the outflow from supernovae occur later than the two 'dips'. This means that the two 'dips' cannot be reproduced by outflow and inflow. what are mass parameters now?

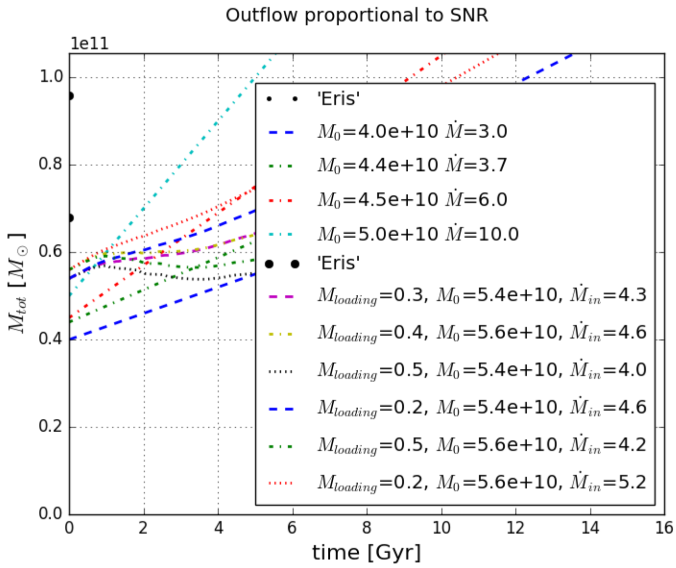


Figure 1.6: Total baryonic mass of galaxy over time. what is the initial mass of gas and inflow rate? The outflow adds a non-linear effect to the total mass.

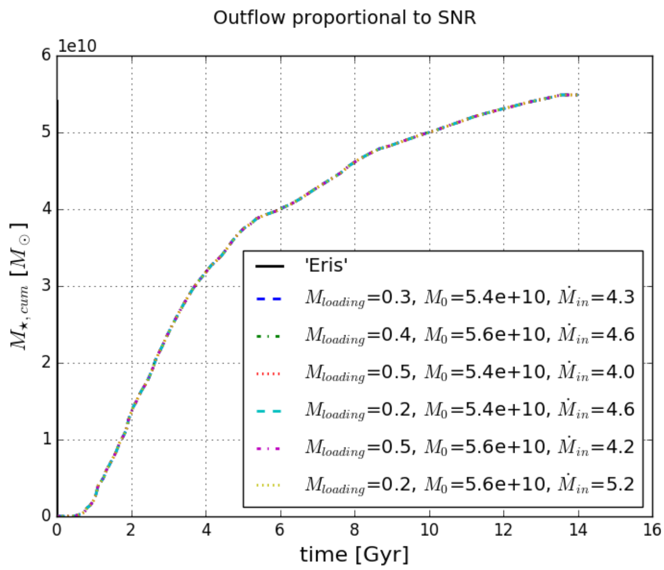


Figure 1.7: Cumulative stellar mass formed against time for X `'Omega'` models, and the `'Eris'`-simulation. The outflow removes mass, but there is still enough gas to form stars from the `'Eris'` star formation rate.

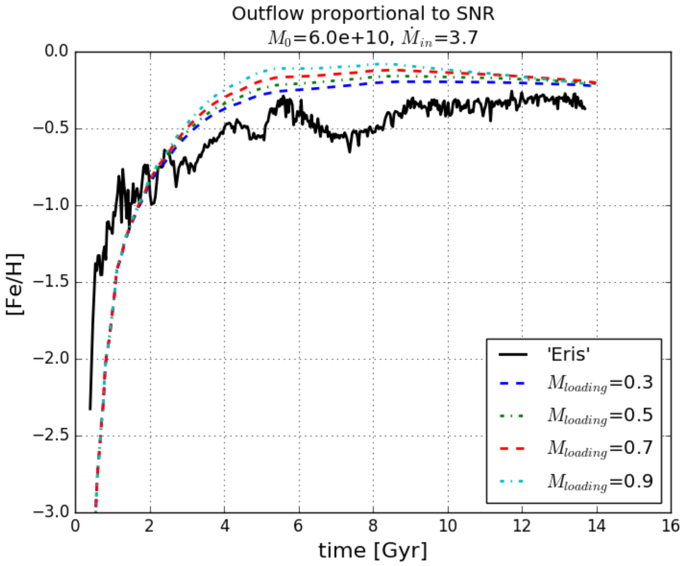


Figure 1.8: Iron abundance in the models with varying mass-loading parameters(solar masses of outflow per solar mass of supernova). The data from `'Eris'` show two 'dips' from the increasing tendency. The dips could not be reproduced by outflow of enriched material and inflow of hydrogen. Outflow peaks over the 'dips', reducing the spectroscopic abundance, however the effect is wide and smeared out over a time range beyond both 'dips'.

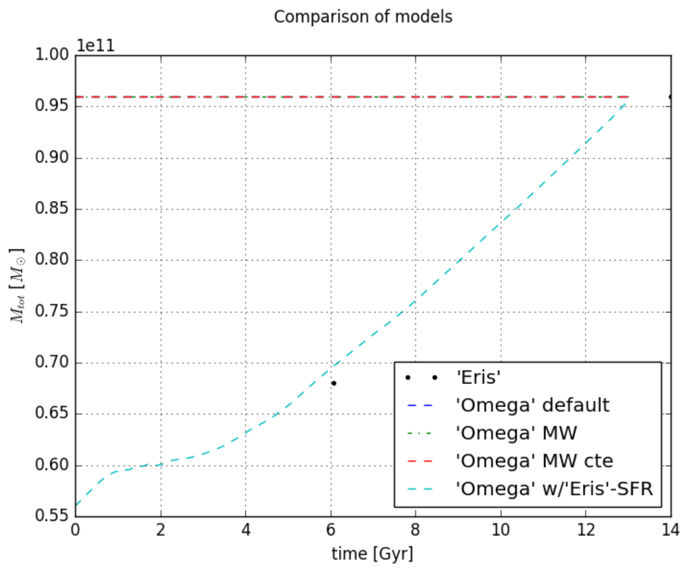


Figure 1.9: Total baryonic mass of galaxy over time for `'Eris'`, , , and `'Omega'` with all default parameters. Only the model reproduces the total mass content found in `'Eris'`, represent by two datapoints from table ??.

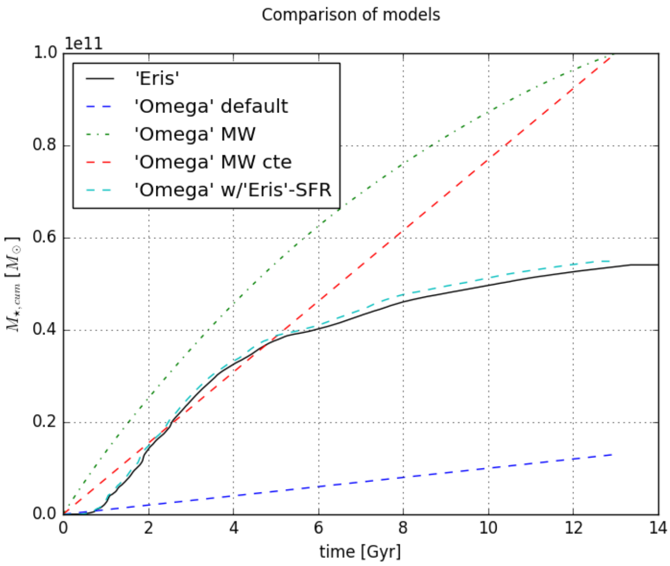


Figure 1.10: Cumulative stellar mass formed over time for `'Eris'`, , , and `'Omega'` with all default parameters. All predefined models massively undershoots or overshoots the measured star formation in `'Eris'`. The model accurately reproduces the cumulative stellar formation with `'Eris'`. The slight variation between the model and `'Eris'` is due to low numerical resolution.

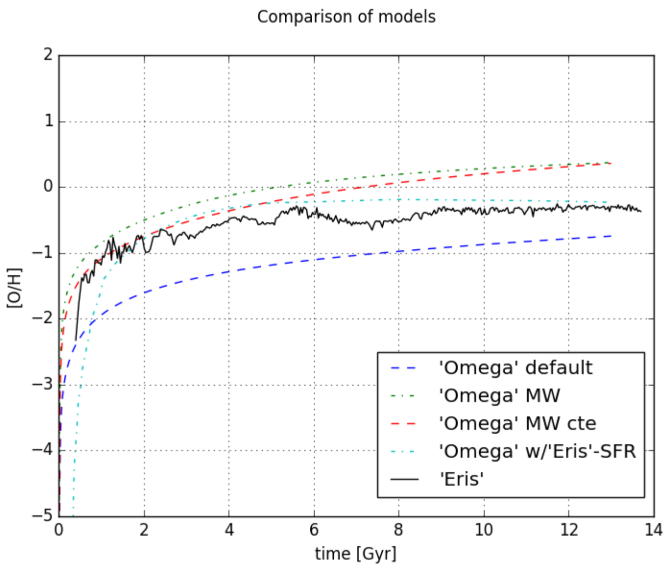


Figure 1.11: Spectroscopic iron over time for `'Eris'`, , , and `'Omega'` with all default parameters. The model has almost no star formation in the very beginning of the integration, this leads to a delayed chemical evolution that can be seen in the graph. The predefined models have some(if not much) star formation from the first integration step to the last. This implies that chemical evolution can begin much sooner, as can be seen in the graphs.

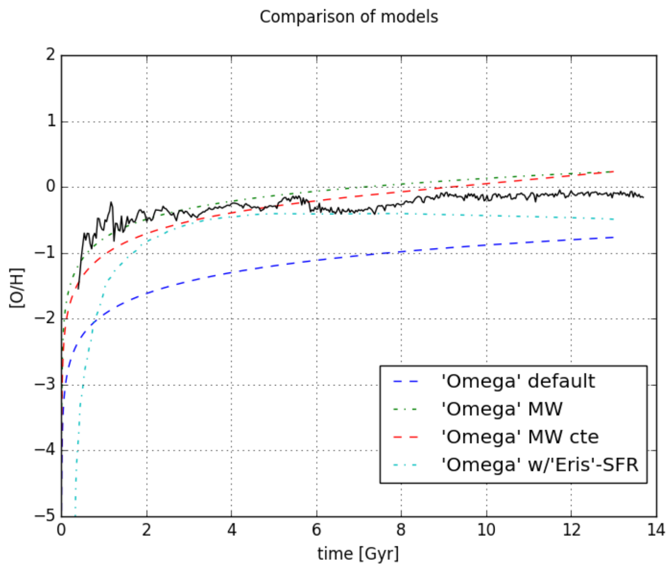


Figure 1.12: Spectroscopic oxygen over time for `'Eris'`, , , and `'Omega'`with all default parameters. The model has almost no star formation in the very beginning of the integration, this leads to a delayed chemical evolution that can be seen in the graph. The predefined models have some(if not much) star formation from the first integration step to the last. This implies that chemical evolution can begin much sooner, as can be seen in the graphs.

1.3.3 Effect of AGB stars, massive stars, population III stars and Type 1a Supernovae

what parameters are used to mess with stars?

Chemical enrichment of galactic gas (the interstellar medium), comes from stars. quick recap of theory section Hydrogen and helium from the primordial gas is locked into a star, where fusion processes transmutates the elements into heavier elements up to iron. In the process some heavier elements are created, mostly by neutron capture processes. At the end of the stars life some of the material will be ejected back into the interstellar medium. Asymptotic giant branch stars are low mass stars at the end of their life, they eject mass via episodes known as helium flashes, leaving a white dwarf behind. Massive stars end their life as typeII supernovae, ejecting most of their enriched material leaving a neutron star or black hole behind. The very first stars, with no initial chemical enrichment, or metallicity, are called population III stars. They are generally believed to have a slightly different initial mass distribution function, and could produce slightly different distributions of metals. The exact science of population III stars is not well defined, as none has been observed, but the stellar population is one of the options of the `'Omega'` model and should therefor be taken into consideration when comparing `'Eris'`and `'Omega'`. The remnants, white dwarves, neutron stars and black holes, are not the end of the story, binary star systems can bring new life to these dead bodies. A white dwarf accreting plasma from the envelope of a binary star can accumulate enough mass to ignite a core-collapse that ejects more enriched matter into the interstellar medium. Two neutron stars in orbit around eachother can loose gravitational energy to gravitational waves and merge. Such an energetic event will create alot of heavy elements and eject alot of the mass of the binary system with great velocity. Similar gravitational events can occur between two black holes and a black hole and a neutron star. The last two event will be ignored because two black holes do not create or eject any heavy elements (or any elements at all), while black hole neutron star merger is not included in `'Eris'`.

add plot about agb/massive yield tables

plot yield tables here

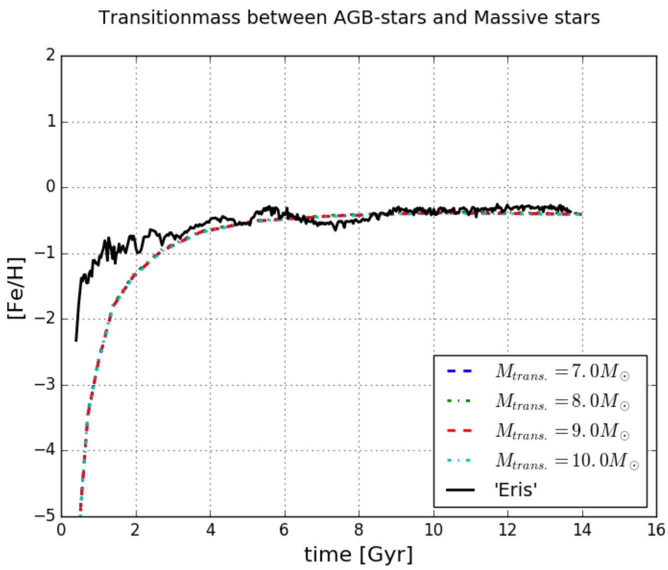


Figure 1.13: The transitionmass is the value where the star goes from being considered an asymptotic giant branch star to a massive star and usually considered to be 8 $M_{\odot}$. Stars with initial mass below this threshold leave the main sequence to become asymptotic giant branch star that ejects enriched mass in helium flashes and leaves a white dwarf. Stars with initial mass above this threshold leave the main sequence, goes through the giant branch burning heavier layers of stellar material, ending their life as a core collapse supernova. It is clear from the plot that varying the transitionmass between 7 $M_{\odot}$ and 10 $M_{\odot}$ does not significantly change the yield output of the `'Omega'` model

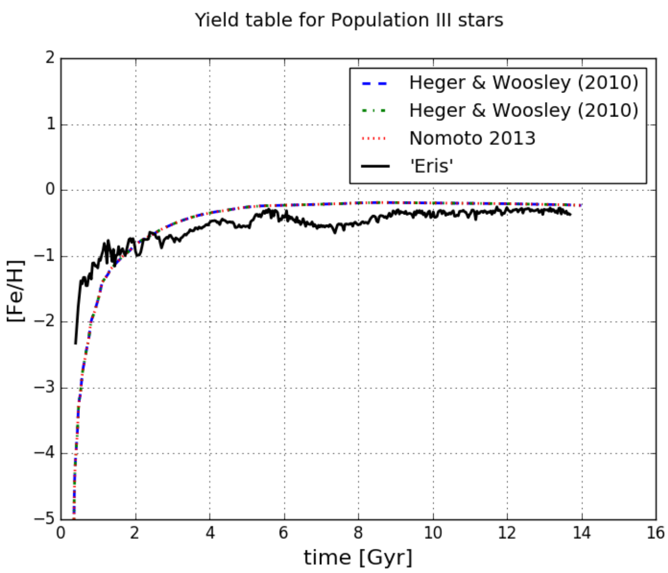


Figure 1.14: The plot shows iron abundance for `'Eris'` data and `'Omega'`with different yield tables for population III stars. Population III stars are stars with no initial metallicity, meaning the first stars. These stars are believed to be bigger, but have not been observed. It is clear that the different yield tables gives no variation in iron abundance, even in early times.

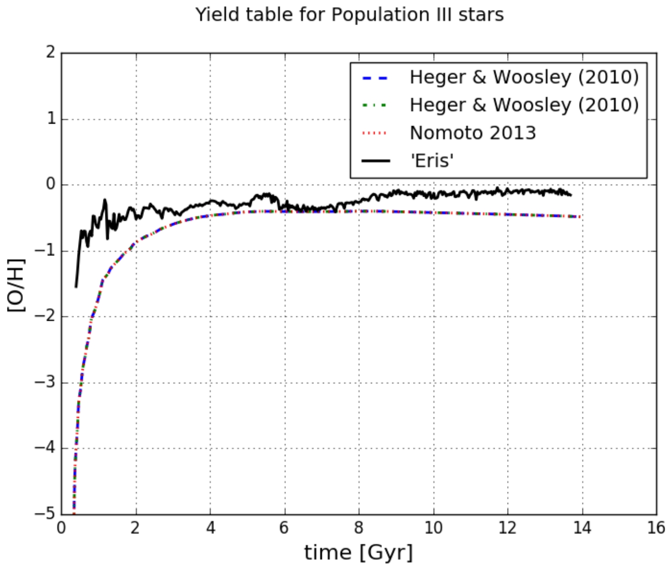
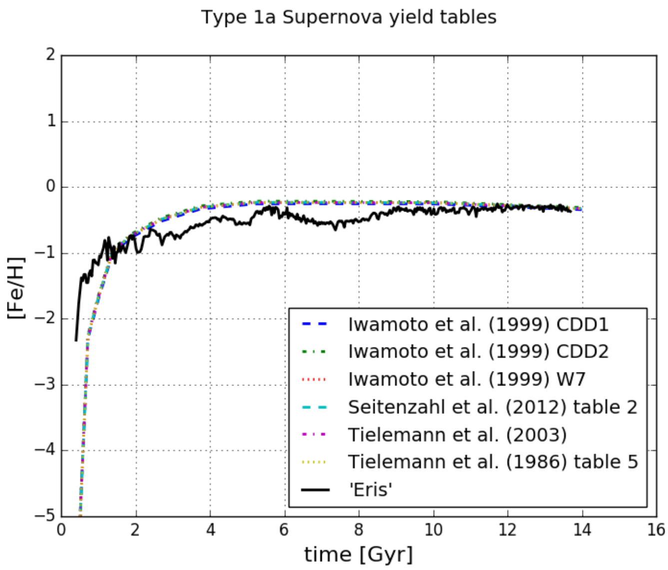


Figure 1.15: The plot shows oxygen abundance for `'Eris'` data and `'Omega'`with different yield tables for population III stars. Population III stars are stars with no initial metallicity, meaning the first stars. These stars are believed to be bigger, but have not been observed. The yield tables gives the isotopic ejecta from supernovae. It is clear that the different yield tables gives no variation in iron abundance, even in early times.



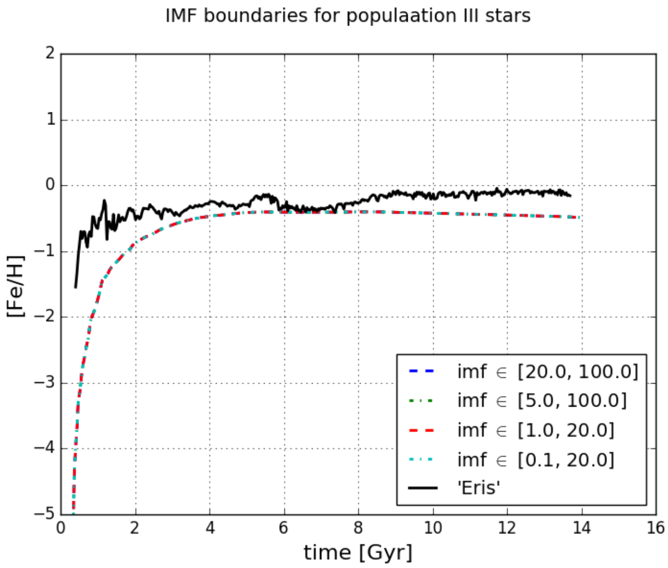


Figure 1.16: The plot shows iron abundance for `'Eris'` data and `'Omega'`with different mass-function boundaries for population III stars. Population III stars are stars with no initial metallicity, meaning the first stars. These stars are believed to be bigger, but have not been observed. The boundaries of the mass function change the distribution of initial mass of the population III stars. It is clear that the different yield tables gives no variation in iron abundance, even in early times.

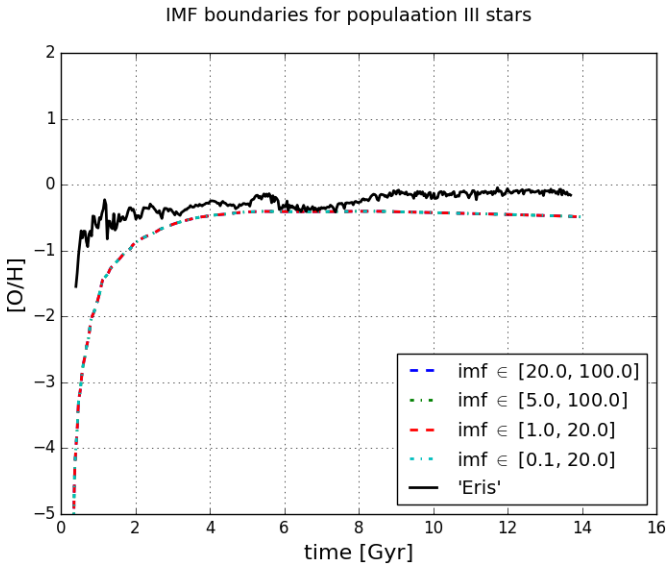
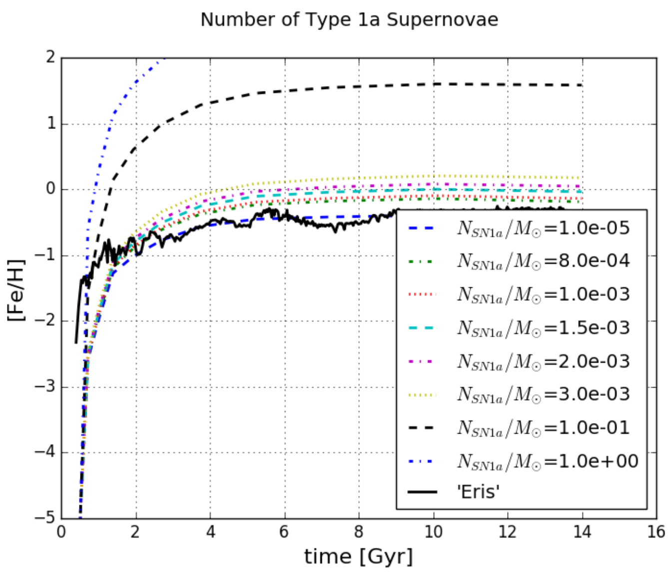


Figure 1.17: The plot shows oxygen abundance for `'Eris'` data and `'Omega'`with different mass-function boundaries for population III stars. Population III stars are stars with no initial metallicity, meaning the first stars. These stars are believed to be bigger, but have not been observed. The boundaries of the mass function change the distribution of initial mass of the population III stars. It is clear that the different yield tables gives no variation in iron abundance, even in early times.



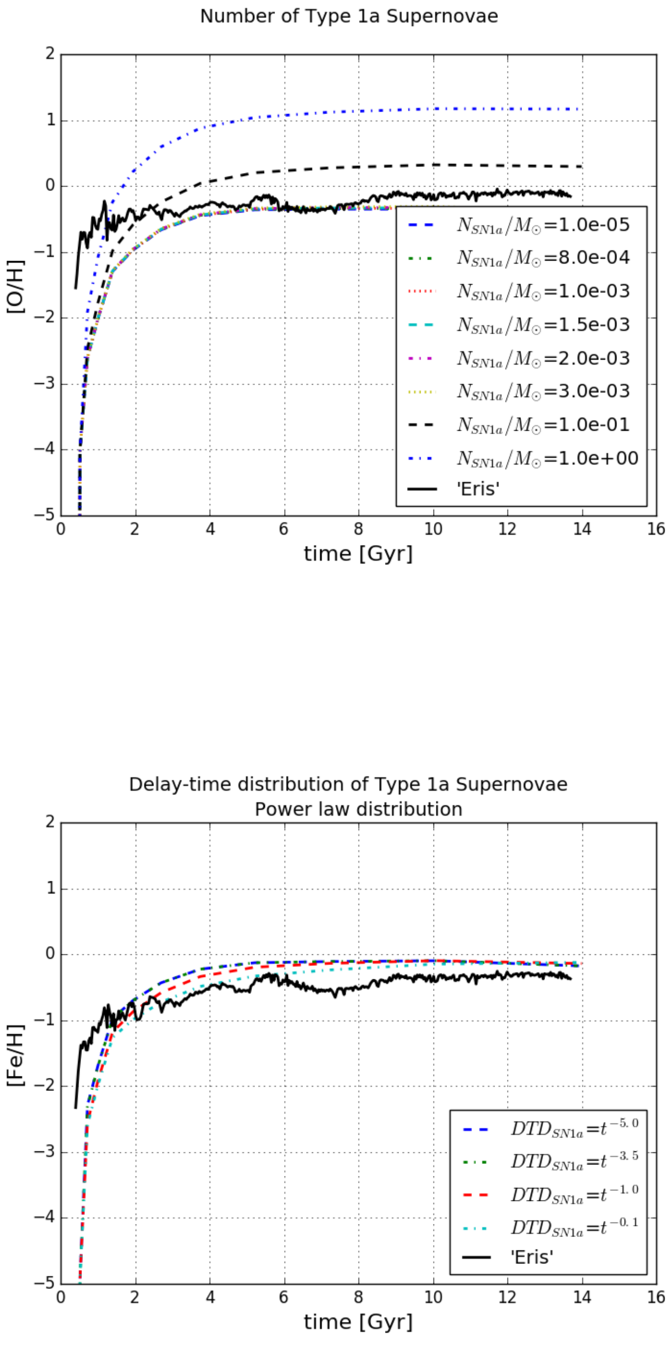
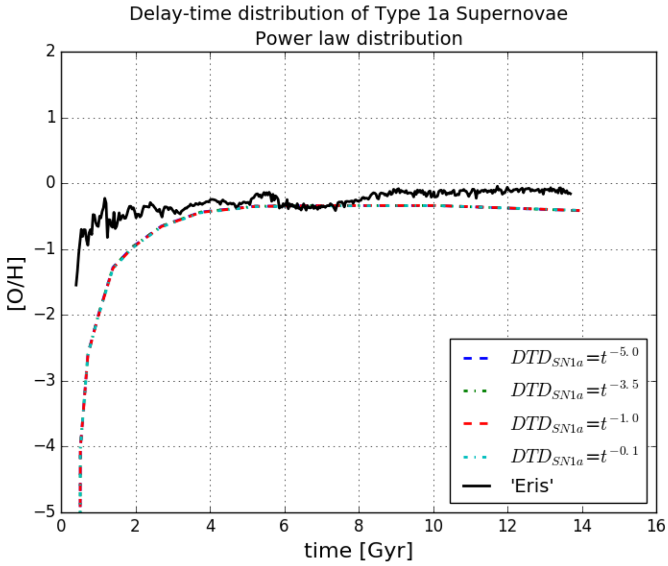
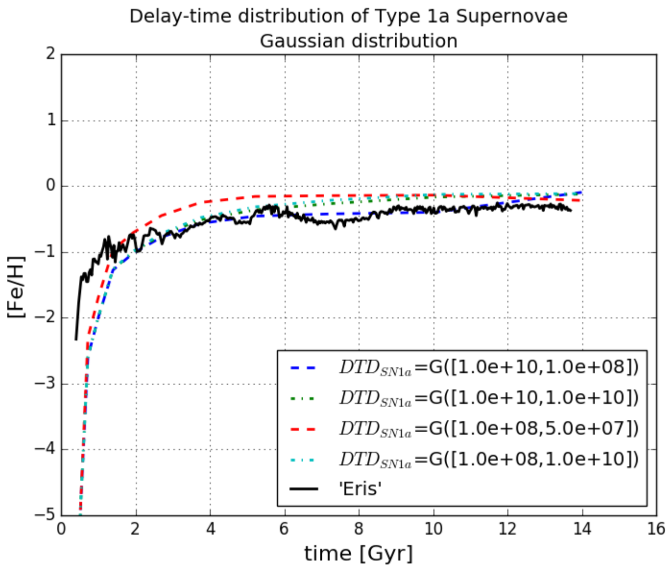

Number of Type 1a Supernovae
[O/H]
time [Gyr]
$N_{SN1a}/M_{\odot}$=1.0e-05
$N_{SN1a}/M_{\odot}$=8.0e-04
$N_{SN1a}/M_{\odot}$=1.0e-03
$N_{SN1a}/M_{\odot}$=1.5e-03
$N_{SN1a}/M_{\odot}$=2.0e-03
$N_{SN1a}/M_{\odot}$=3.0e-03
$N_{SN1a}/M_{\odot}$=1.0e-01
$N_{SN1a}/M_{\odot}$=1.0e+00
'Eris'
Delay-time distribution of Type 1a Supernovae
Power law distribution
[Fe/H]
time [Gyr]
$DTD_{SN1a}=t^{-5.0}$
$DTD_{SN1a}=t^{-3.5}$
$DTD_{SN1a}=t^{-1.0}$
$DTD_{SN1a}=t^{-0.1}$
'Eris'

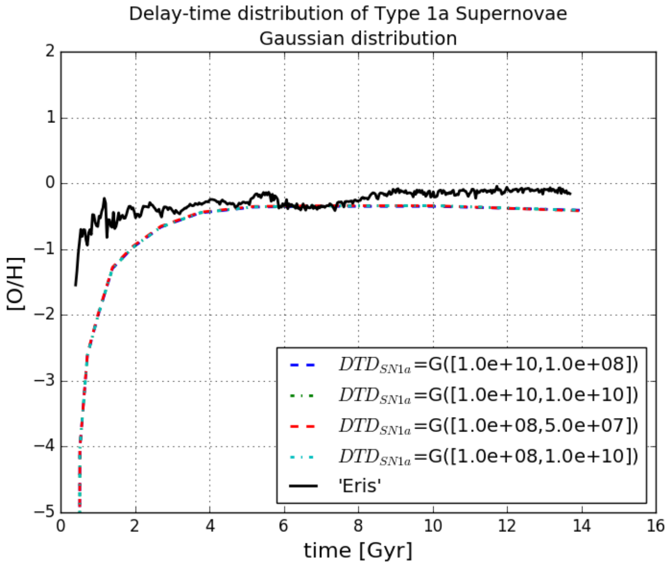
Figure 1.18:

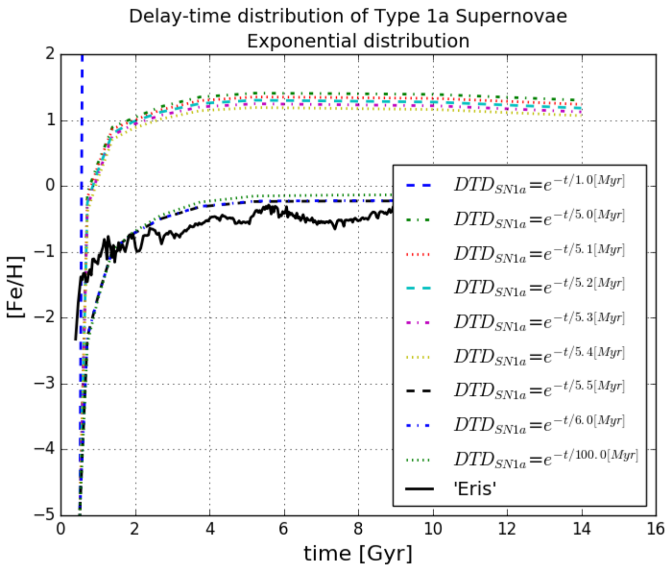


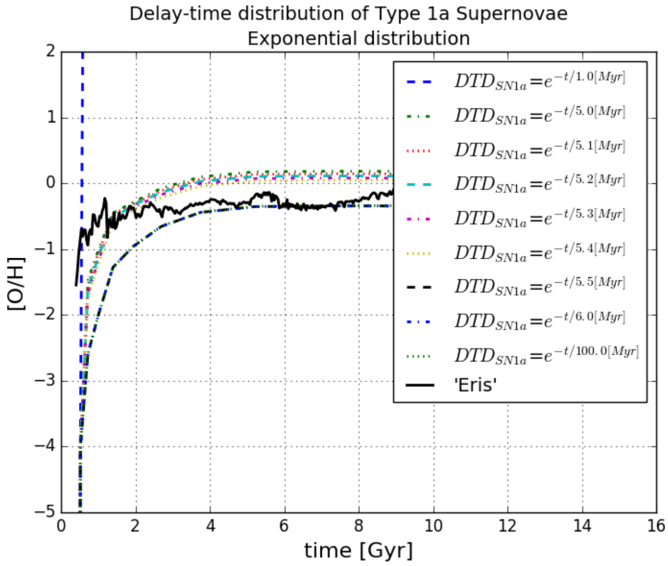
Delay-time distribution of Type 1a Supernovae
Power law distribution
[O/H]
time [Gyr]
DTD_{SN1a}=$t^{-5.0}$
DTD_{SN1a}=$t^{-3.5}$
DTD_{SN1a}=$t^{-1.0}$
DTD_{SN1a}=$t^{-0.1}$
'Eris'



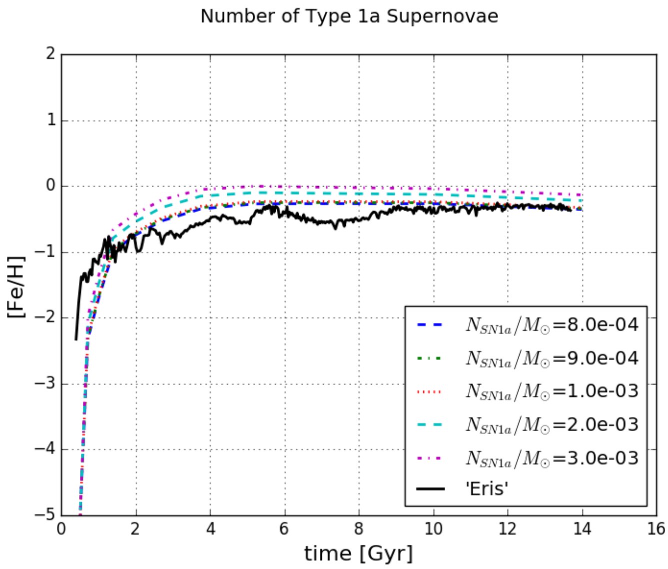
Delay-time distribution of Type 1a Supernovae
Gaussian distribution
[Fe/H]
time [Gyr]
DTD_{SN1a}=G([1.0e+10,1.0e+08])
DTD_{SN1a}=G([1.0e+10,1.0e+10])
DTD_{SN1a}=G([1.0e+08,5.0e+07])
DTD_{SN1a}=G([1.0e+08,1.0e+10])
'Eris'


Delay-time distribution of Type 1a Supernovae
Gaussian distribution
[O/H]
time [Gyr]
DTD_{SN1a}=G([1.0e+10,1.0e+08])
DTD_{SN1a}=G([1.0e+10,1.0e+10])
DTD_{SN1a}=G([1.0e+08,5.0e+07])
DTD_{SN1a}=G([1.0e+08,1.0e+10])
'Eris'

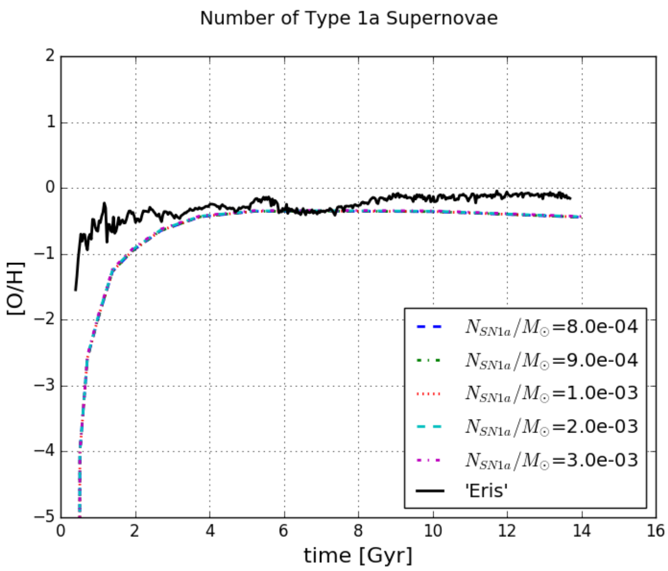

Delay-time distribution of Type 1a Supernovae
Exponential distribution
[Fe/H]
time [Gyr]
$DTD_{SN1a}=e^{-t/1.0[Myr]}$
$DTD_{SN1a}=e^{-t/5.0[Myr]}$
$DTD_{SN1a}=e^{-t/5.1[Myr]}$
$DTD_{SN1a}=e^{-t/5.2[Myr]}$
$DTD_{SN1a}=e^{-t/5.3[Myr]}$
$DTD_{SN1a}=e^{-t/5.4[Myr]}$
$DTD_{SN1a}=e^{-t/5.5[Myr]}$
$DTD_{SN1a}=e^{-t/6.0[Myr]}$
$DTD_{SN1a}=e^{-t/100.0[Myr]}$
'Eris'



Delay-time distribution of Type 1a Supernovae
Exponential distribution
$DTD_{SN1a}=e^{-t/1.0[Myr]}$
$DTD_{SN1a}=e^{-t/5.0[Myr]}$
$DTD_{SN1a}=e^{-t/5.1[Myr]}$
$DTD_{SN1a}=e^{-t/5.2[Myr]}$
$DTD_{SN1a}=e^{-t/5.3[Myr]}$
$DTD_{SN1a}=e^{-t/5.4[Myr]}$
$DTD_{SN1a}=e^{-t/5.5[Myr]}$
$DTD_{SN1a}=e^{-t/6.0[Myr]}$
$DTD_{SN1a}=e^{-t/100.0[Myr]}$
'Eris'
[O/H]
time [Gyr]



Number of Type 1a Supernovae
$N_{SN1a}/M_{\odot}$=8.0e-04
$N_{SN1a}/M_{\odot}$=9.0e-04
$N_{SN1a}/M_{\odot}$=1.0e-03
$N_{SN1a}/M_{\odot}$=2.0e-03
$N_{SN1a}/M_{\odot}$=3.0e-03
'Eris'
[Fe/H]
time [Gyr]


Number of Type 1a Supernovae
[O/H]
time [Gyr]
$N_{SN1a}/M_\odot$=8.0e-04
$N_{SN1a}/M_\odot$=9.0e-04
$N_{SN1a}/M_\odot$=1.0e-03
$N_{SN1a}/M_\odot$=2.0e-03
$N_{SN1a}/M_\odot$=3.0e-03
'Eris'

1.3.4 Binary neutron star mergers

what are realistic parameters? uncertainty of them? what are the input parameter-space used?

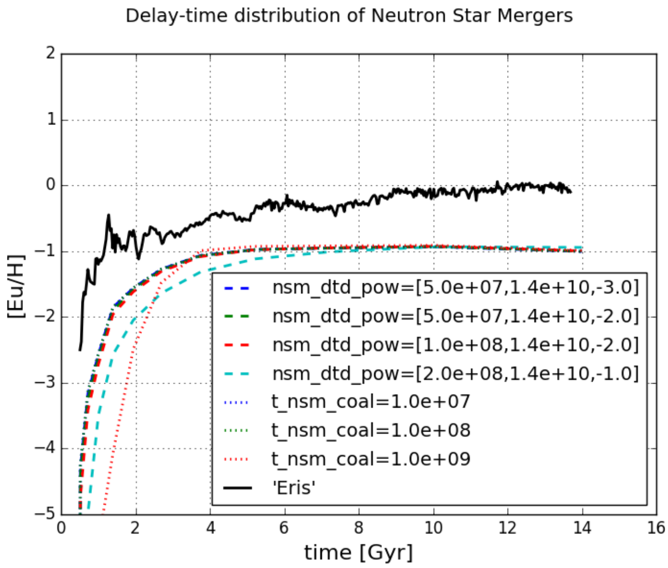


Figure 1.19: Abundance of europium in `'Eris'` simulation and `'Omega'` models for galactic time in Gyrs. There are two main ways to calculate the delay-time of a neutron star merger in `'Omega'`: one is a powerlaw distribution in time(with boundaries at minimum and maximum time), while another is setting a time after which all neutron star binaries merge, called a coalescence time.

what does `'Eris'` use?

In order to reproduce the `'Eris'` spectroscopic abundances, `'Omega'` must synthesize more europium at an earlier time, this is achieved by a steep distribution with early minimum-time. It is clear from the plot that all models behave similar at late times, regardless of delay-time distribution. There is also little difference between a short coalescence time or a powerlaw distribution with short minimum time.

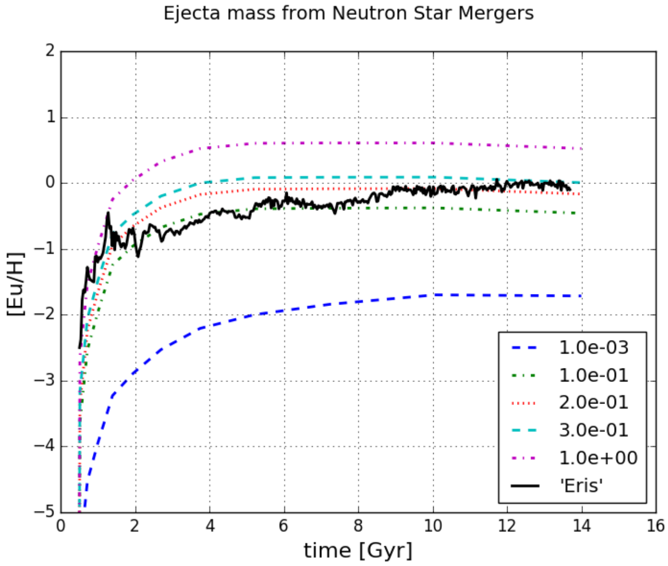


Figure 1.20: Spectroscopic europium abundance against galactic time for `'Eris'`-data and several `'Omega'`models. In the models the mass ejected from each neutron star merger have been modified. Modifying the mass ejected from each event will just scale the total europium content up and down. Ejecting 0.2-0.3 $M_\odot$ per event gives a pretty decent fit to late time europium and early time europium. However for the 'dips' between 2 and 8 Gyrs, the `'Omega'` model overshoots the `'Eris'` data.

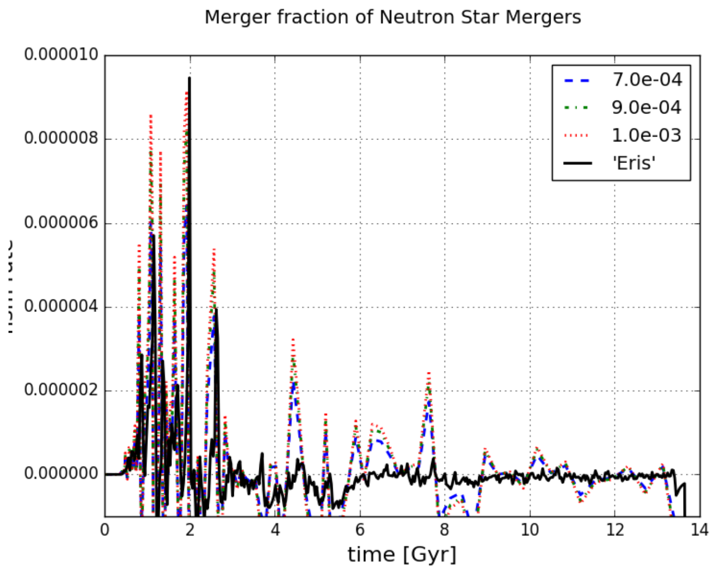


Figure 1.21:

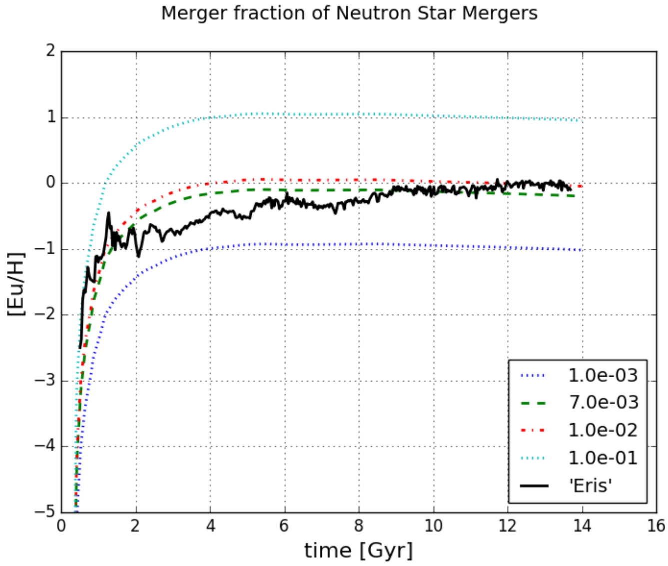


Figure 1.22:

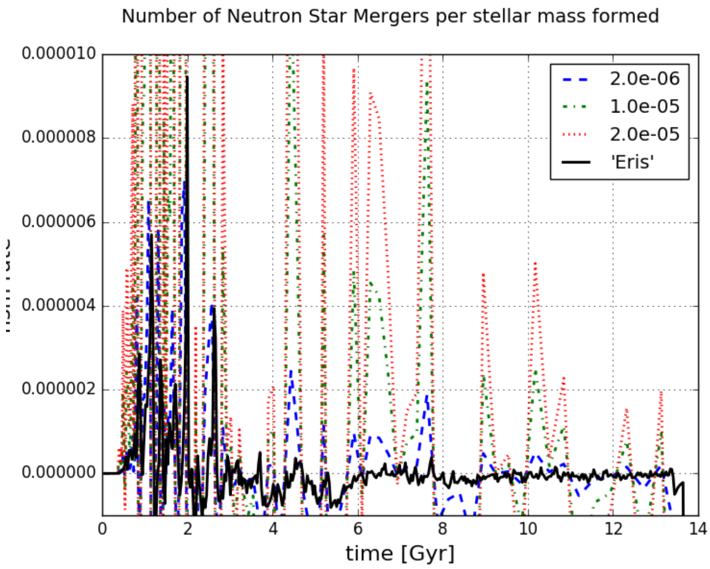


Figure 1.23:

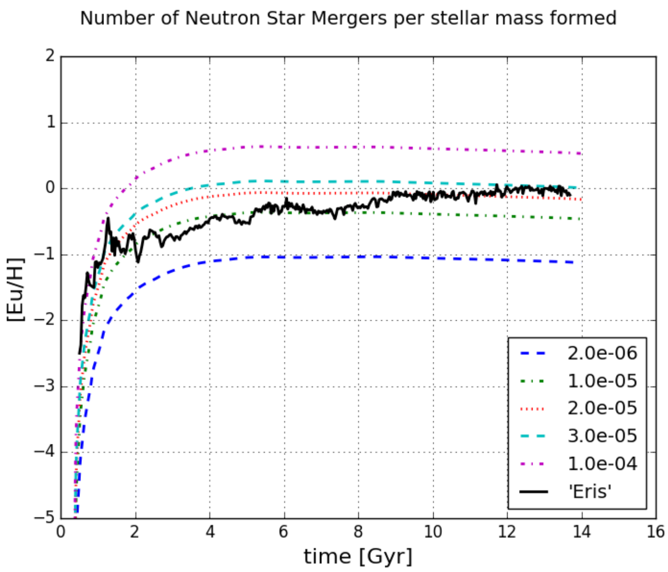


Figure 1.24:

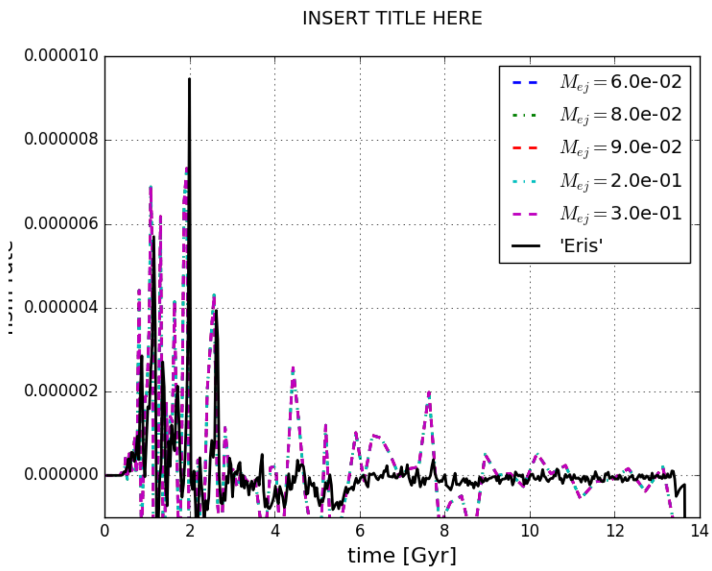


Figure 1.25:

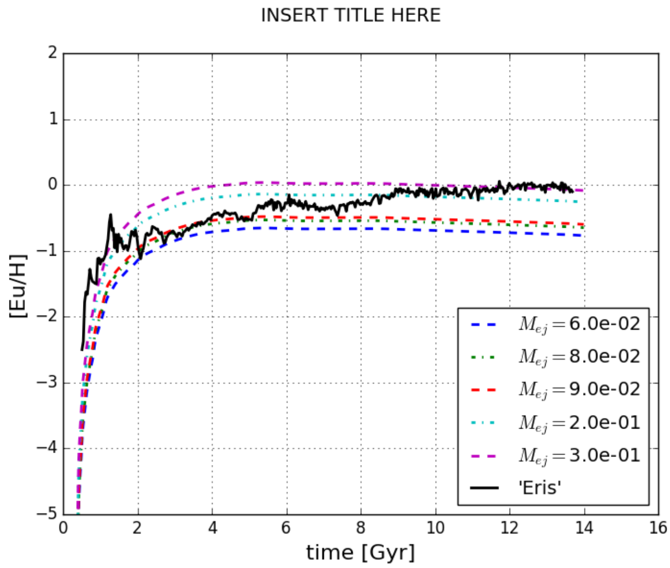


Figure 1.26:

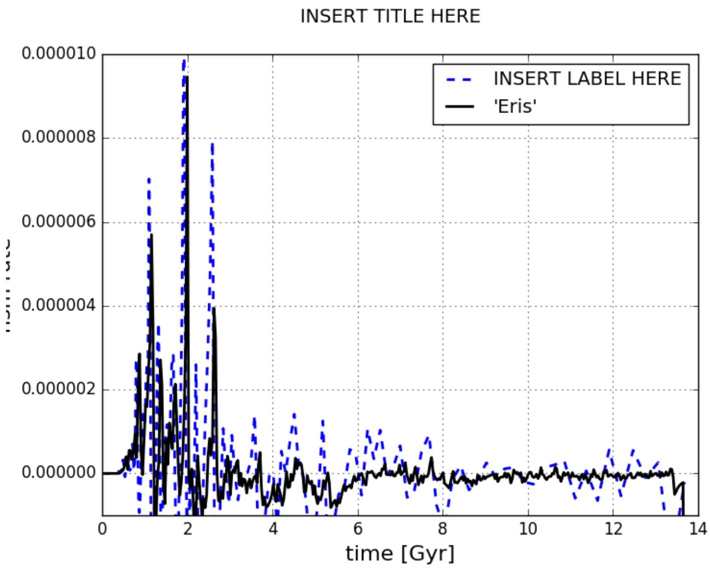


Figure 1.27:

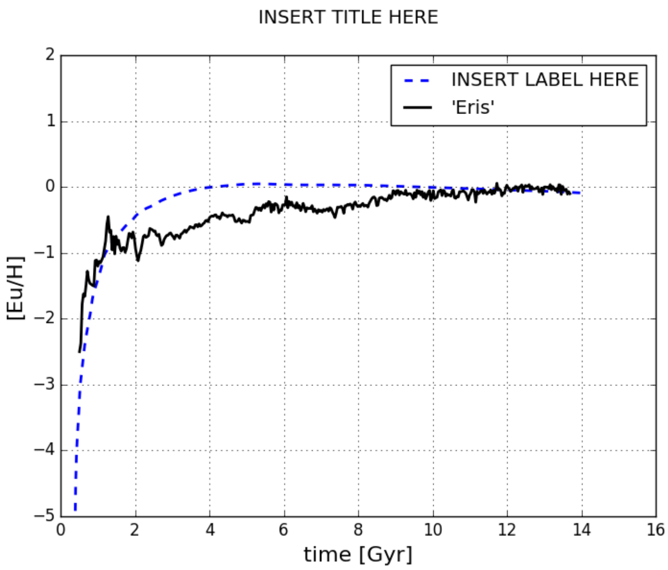

INSERT TITLE HERE
INSERT LABEL HERE
'Eris'
[Eu/H]
time [Gyr]
2
1
0
−1
−2
−3
−4
−5
0
2
4
6
8
10
12
14
16

Figure 1.28:

1.3.5 Size of timesteps

add plots from timestep analysis

1.3.6 Final parameters of fitting

add plots from final bestfit-folder