Meeting 10/11/21

10 November 2021 05:08

Meeting with David and Laura 2:30

- David said to download the github repository of Rehilae and look at all the variables that Rehilae uses in their sims
- These include things like Rho lya, nion, fesc etc.
- Just look at how they work, Then work on stuff like:

1. Start trying to find functions that are good plots of Rho Uv (They must be above and not below) and not as high as Rho Lya
2. Play around with nion and Qdot as these already utilise the scaling relation and convert so we no longer need to scale rho uv from hertz
3. Take a look at jorryts paper and compare how nion changes and use it as a sort of baseline to compare whether I am going right or wrong

Week 5/6 - 1

10 November 2021 15:30

Listing variables used

Puv =UV Luminosity density, this is taken using a cubic fit, I don't quite understand how it works yet but ill figure it out

EW0 = Equivilent width, this takes data from sobral 2018 and finds a fit relation between the points, OH this using a function called curve_fit to fit a function of a linear regression, interesting.

Faisst Fesc = Escape Fraction from Faisst 2016, appears to use the same relation fit then plots that relation, again appears to be using curve_fit to fit the function, this is a linear regression

Fesc_Lyc = Escape fraction of lyman continuum photons, presumed to be from sobral 2018, again uses existing data, around 8 data points to fit a function, then extrapolates that function, this appears to be a linear regression

Lya Rho UV = Lyman alpha luminosity density was taken using a quadratic fit of the data from sobral 2018 table 3c, and fitted again using the curve_fit function, the authors ran into a problem however as they do not expect rho lya to drop as sharply as it did using a quadratic variable below z=4. To fix this a power law was fit using the same date from table 3c using another curve_fit but instead using the log of the x component, these were simply combined for separate ranges, distinctly changing between either fit at 5.8

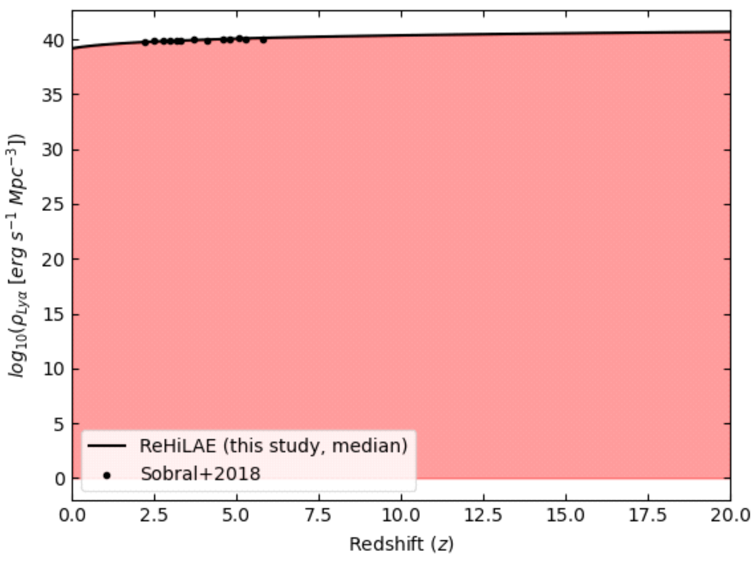
Q_ion = since Qion is also dependent on Lya Rho UV,

n_ion = LyC photons produced per second per Mpc available for re-ionisation, This appears to use the same double fit as Lya Rho Uv.

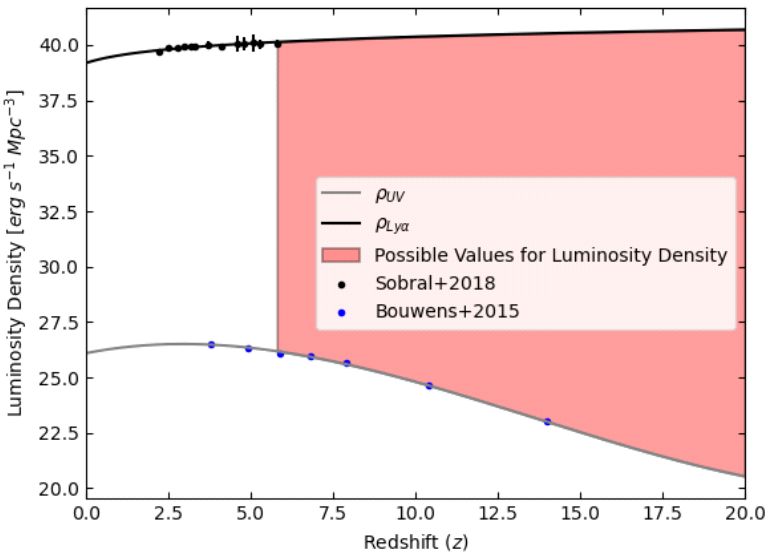
Week 5/6 - 2

13 November 2021 12:30

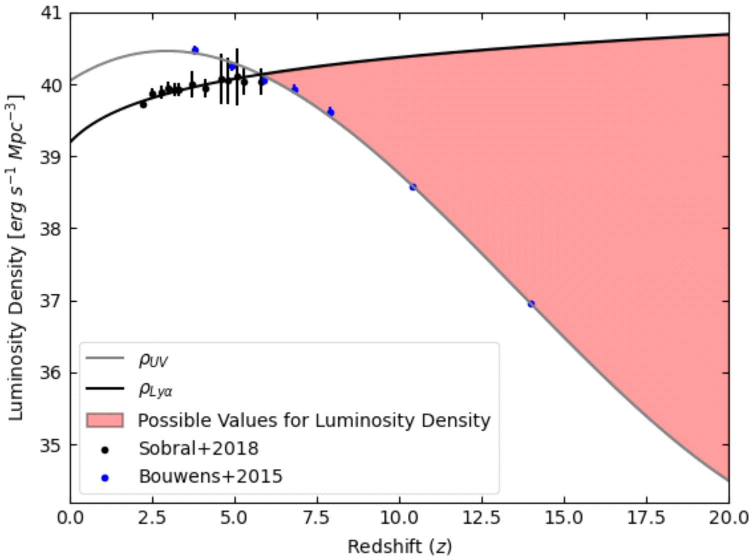
So after playing around with the simulation, we need to find the set of possible values that coincide with reionization. We can first start with Rho Lya.
Since Rho Lya can be extrapolated from Sobral 2018 as ReHilae have already done, this provides the maximum possible value of Rho assuming the contribution is 100% LAEs.



As we know that reionization can only occur through LyC, RhoUV is considered to be the baseline minimum reionization contribu tion where LyC or ionising UV contributes 100% to reionization, and combined with Rho Lya we end up with the following graph



Puv is then scaled to coincide with the end of reionization, we take this value to be z=5.8 and overlap the two curves where rho uv is larger after reionization, and rho lya is larger before the end of reionization as seen here.



41
40
39
38
37
36
35
Luminosity Density [$erg\ s^{-1}\ Mpc^{-3}$]
ρ_{UV}
$\rho_{Ly\alpha}$
Possible Values for Luminosity Density
Sobral+2018
Bouwens+2015
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Redshift (z)

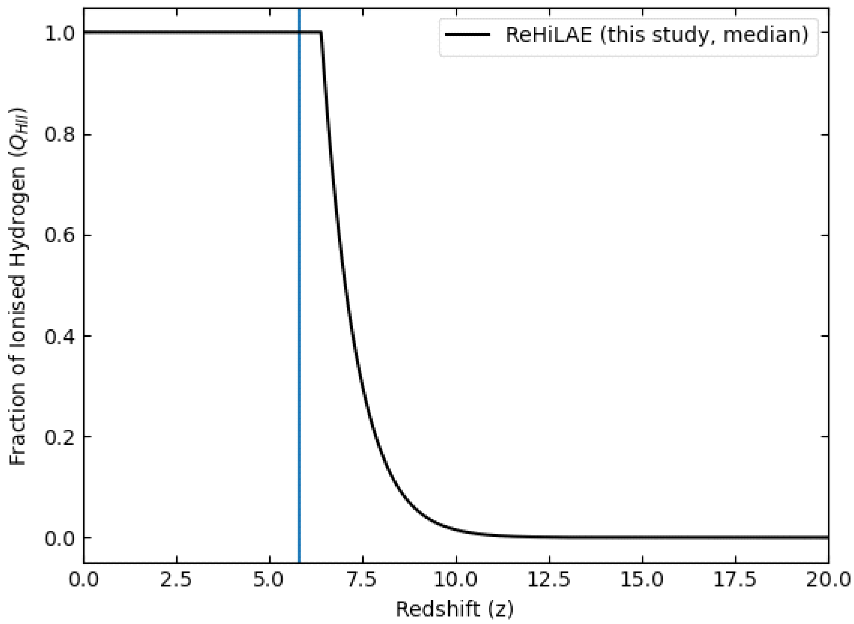
Week 5/6 - 3

14 November 2021 13:00

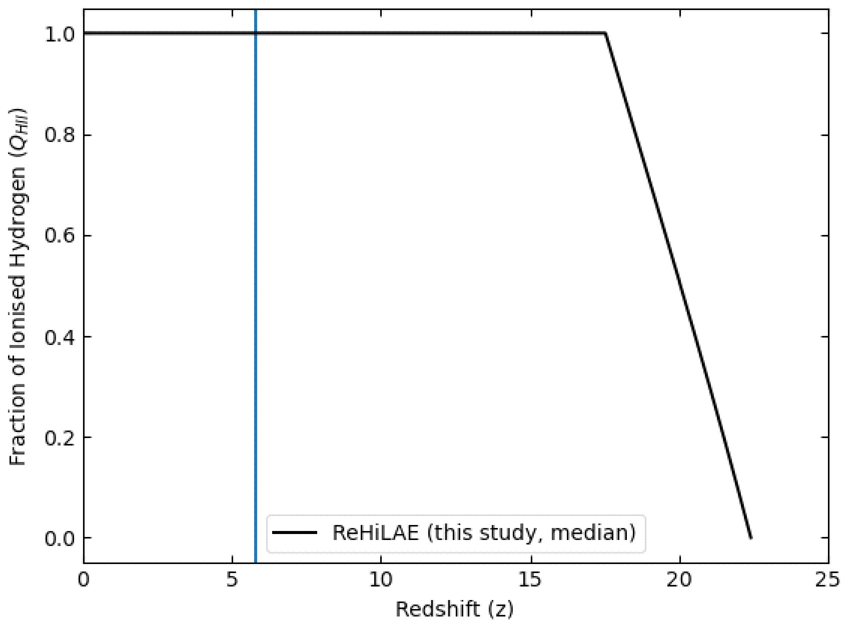
13:00

Using the Rho methods that was found in the previous graphs, we use these methods individually forward to find how the cubic and power law fits give differing reionization time periods.

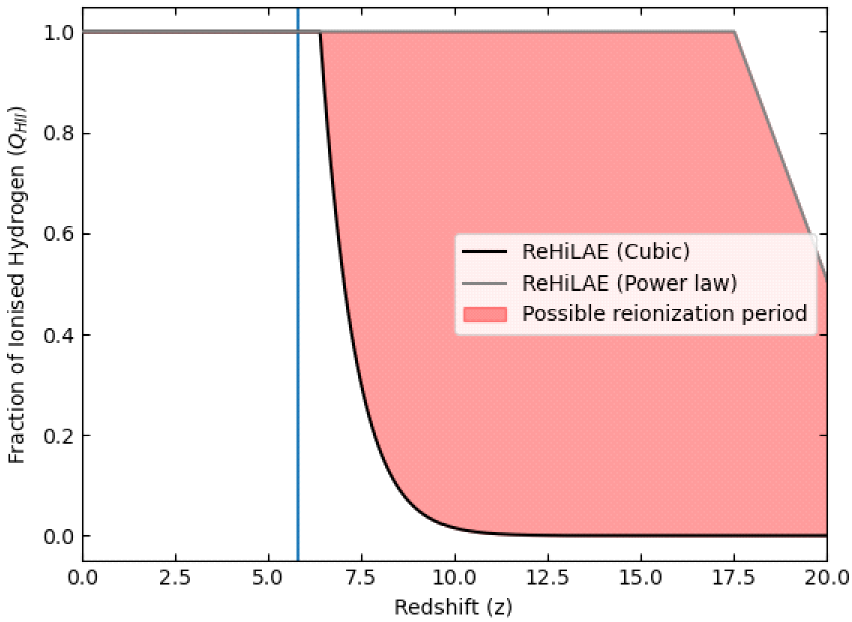
If we use the Cubic Lya Curve, then we end up with the result as follows from this graphs where the blue line shows 5.8 which is our end approximate end of reionization period.



If we use the Power law fit then a different curve completely emerges, it becomes a straight line as one would expect from a logarithmic axis.



If we combine the two and shade the area between them we can give a period in which reionization could have occurred



4:35
But this latter curve seems wrong to me as there is no way it can influence the cubic curve if the power law is only used before 5.8. I will talk with David about this and ask for his opinion.

Meeting 17/11/21

17 November 2021 16:00

Meeting with David and Laura 2:30
- The Plots were not exactly what david wanted, inorder to simulate and study reionization we need to plot actual reionization curves and rho lya and nion data, rather than just filling in an area so that will be my next goal.
    - I need to decide what sort of curves I want to fit - Quadratics would be main priority but linear and other curves could also be interesting.

Essentially I need to think of curves that would be interesting to plot.

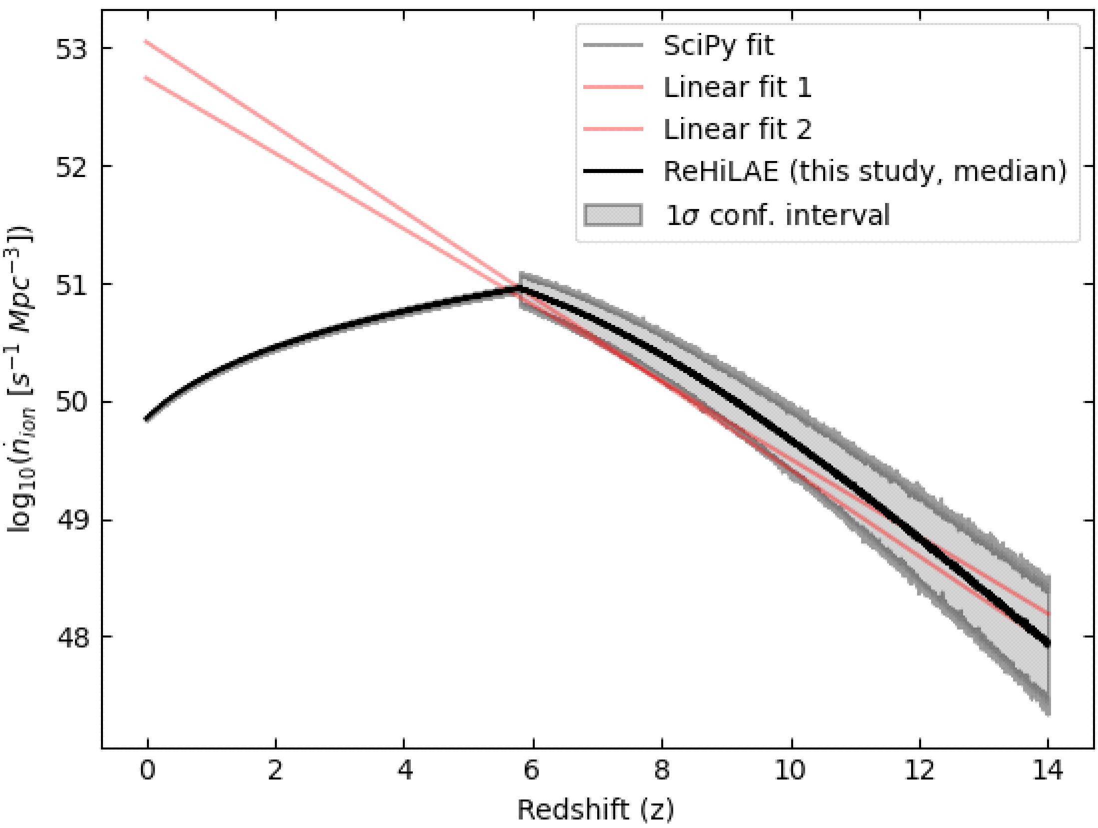
Week 6/7

23 November 2021 13:00

Tuesday (1:00)
Time unfortunately got away from me this week, so I will see how much I can get done.

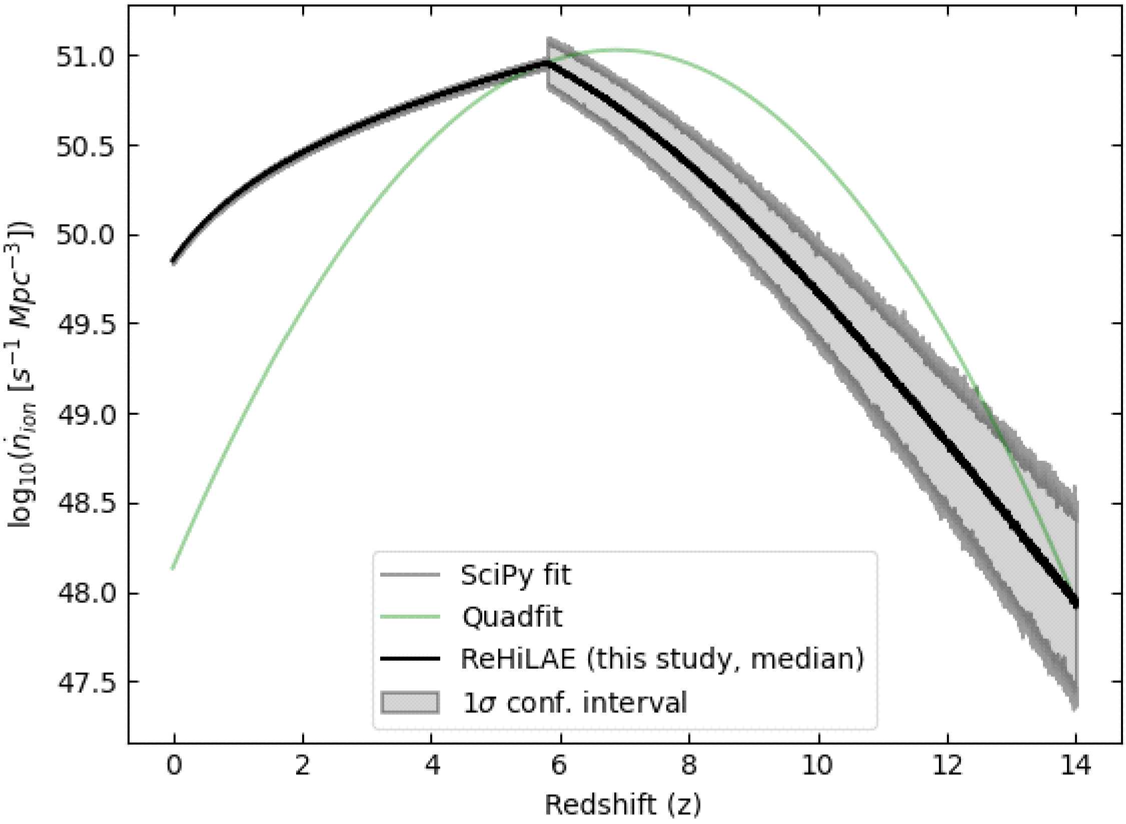
David asked me to fit some functions to the N_ion/Rho lya plots, so that I can get similar results to rehilae but the function needs to be greater than the cubic function but much much less than the continued power law. This gives us again more boundaries of where Rho Lae can be.

Not quite sure where to start, so I will start with a linear regression, Linear fit 1 is calculated through taking the end points of the cubic slope and creating a linear regression. Linear fit 2 is calculated from bowens et al data and fitted through scipy.



We can see that both regressions lie within the 1 sigma confidence interval but could potentially be below the cubic line between z= 6 and z=12, which would mean reionization may occur too slowly.

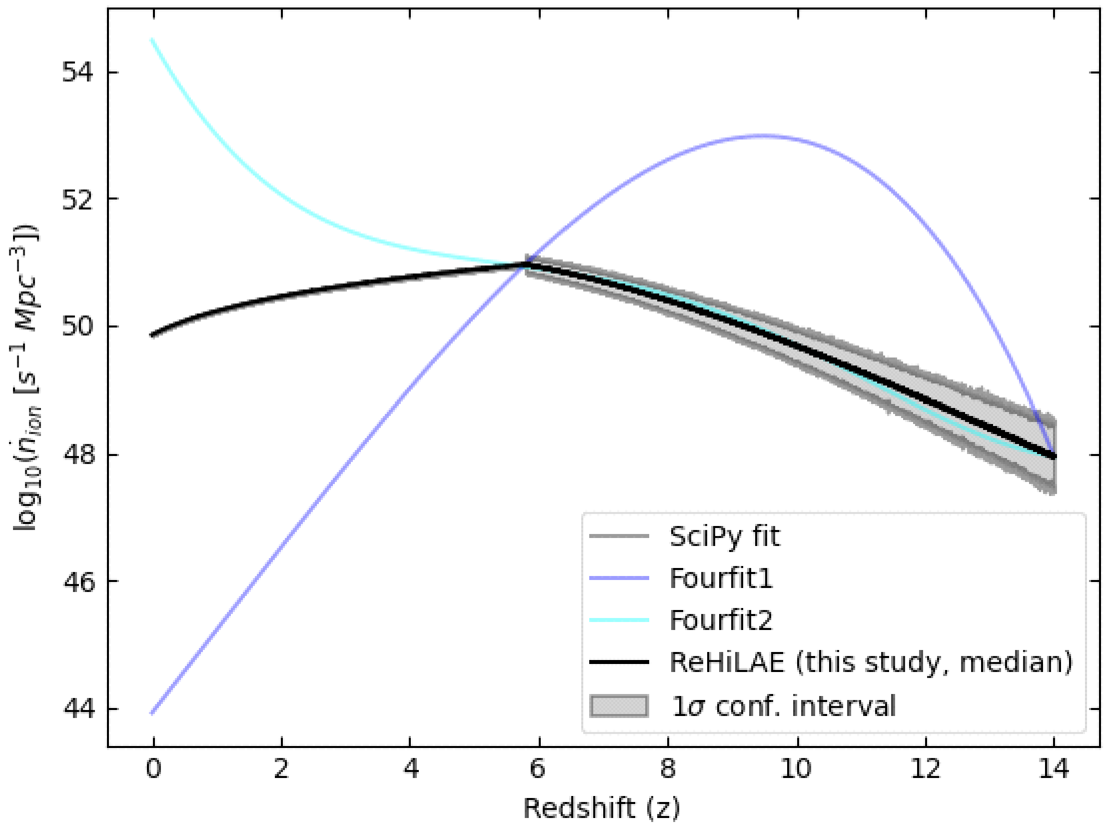
We will now fit a quadratic, this is based similarly to linear 1, where we fit the end points of the cubic slope to a quadratic expression so that we can obtain a parabola that remains above the cubic graph. This is done using pylab.polyfit.



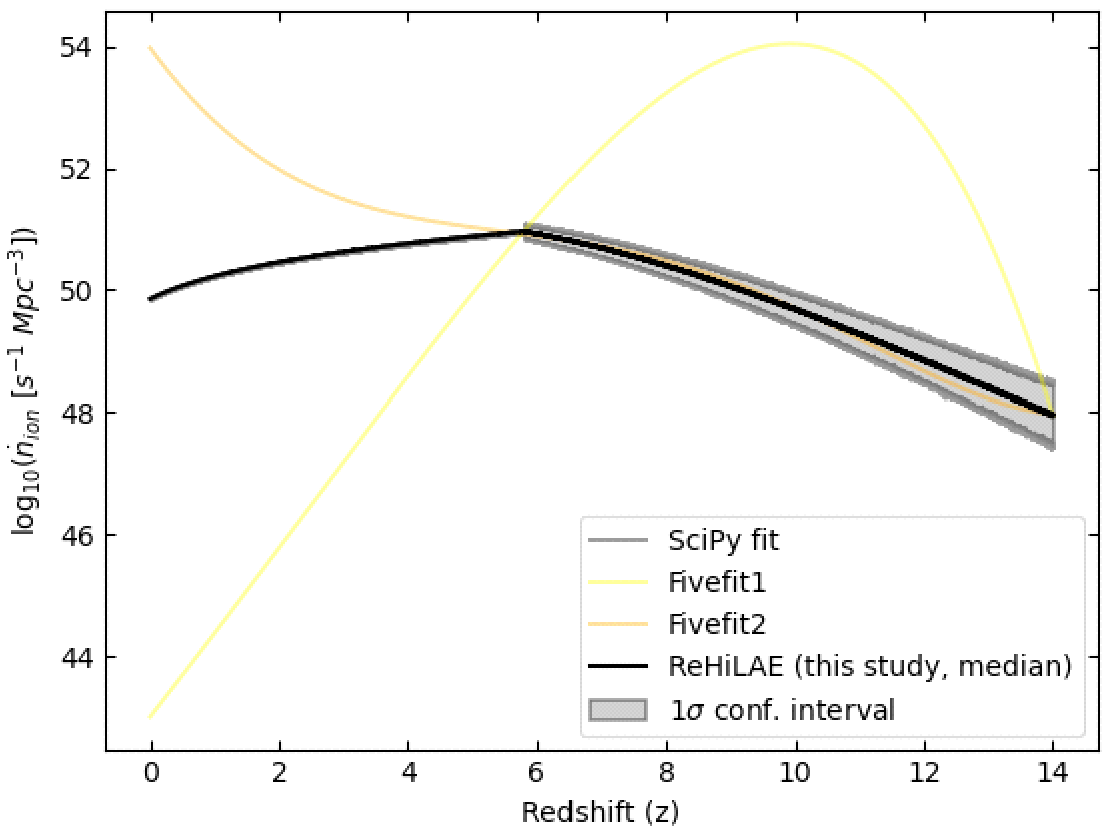
This quadratic function seems to fit quite well but just like the quadratic that Rehilae experimented

We then moved on an did the next set of graphs, in this case, skipping a fit for a cubic function and moving directly

Estimating a 4th power law graph, the dark blue was done using the end points of the cubic function, this unfortunately ends up greatly overestimating the contribution from rho lya above z=5.8 and therefore cannot be used. The cyan fit however was done using the data based on bowens 2015 (the same as the cubic function) and shows a remarkably similar-esqe trend which remains within the confidence interval of the initial cubic function.



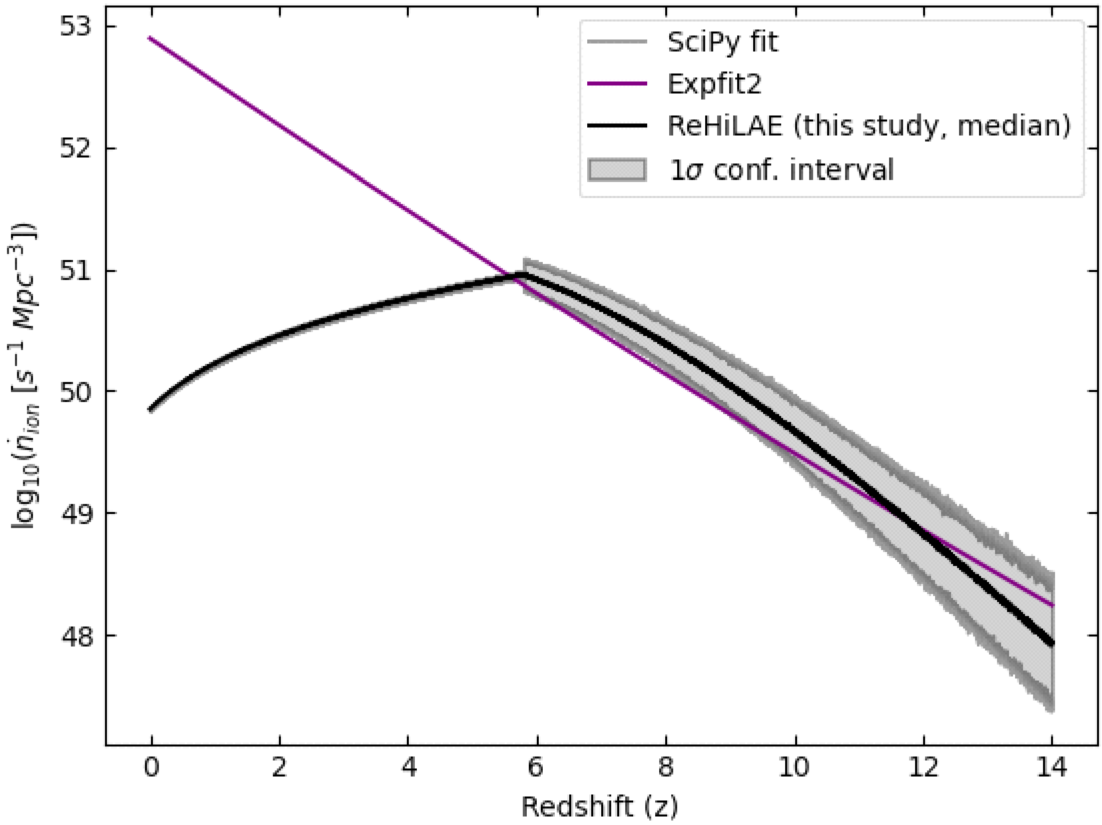
We find the exact same pattern at higher powers of z (z^5)



Where the simple graph is extremely skewed but the graph for multiple fitted data points is remarkably similar

To the results from rehilae. In truth maybe we should expect this as graphs of X^4 and X^5 contain cubic functions and are therefore fundamentally similar.

Lastly for the sake of it, I tried an fitting an exponential curve to the fitted data from Bowens 2015 to see what we would get. This becomes a straight line when on a log graph.

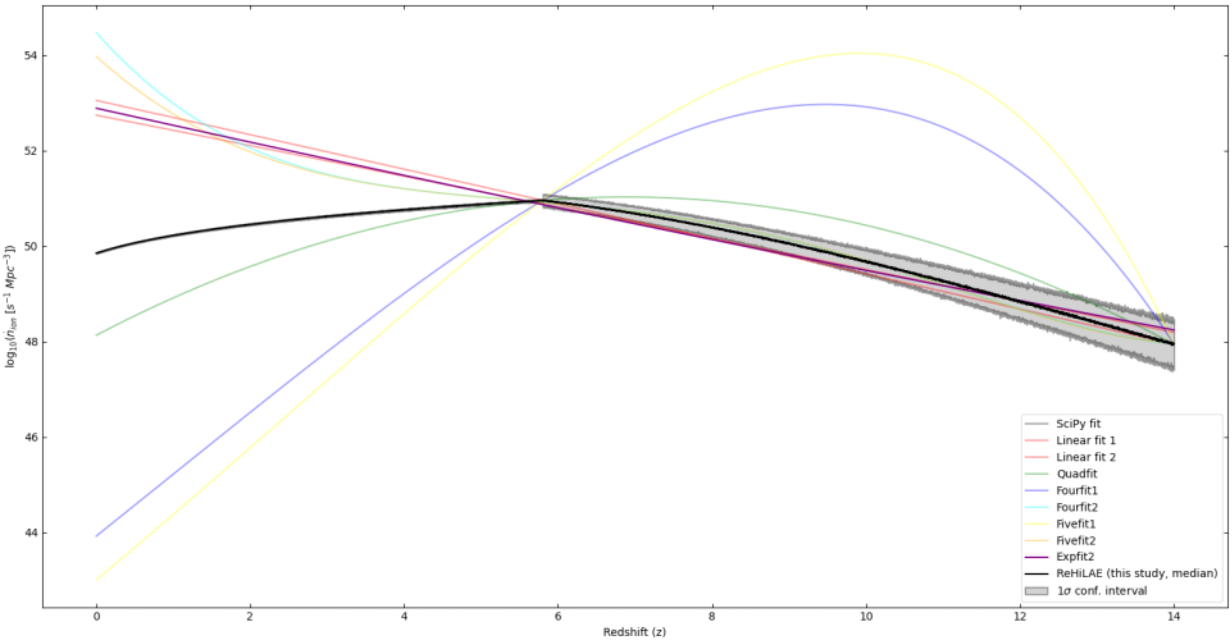


This exponential fit is similar to the linear regression 2 but falls further outside of the confidence interval and under the cubic line for longer, thus this is unlikely to give us an upper bound of rho lya.

All curves that used bowens (2015) data was scaled to match it to rho lya.

19:00

This is my final graph of functions that I decided to plot, I am not sure if this was correct or what I was supposed to do, I could not find any information in jorryts paper about plotting any particular values of n ion, so maybe I will take to talk with David about that. I mean from the graph we can see that the yellow and dark blue functions are immediately not valid, but that most of the others are valid pertubations/alternative forms of the cubic function. Again this seems like it was not what I was supposed to do however I could not think of another way to fit these graphs.



54
52
50
48
46
44
$\log_{10}(\dot{n}_{ion}\ [s^{-1}\ Mpc^{-3}])$
0
2
4
6
8
10
12
14
Redshift (z)
SciPy fit
Linear fit 1
Linear fit 2
Quadfit
Fourfit1
Fourfit2
Fivefit1
Fivefit2
Expfit2
ReHiLAE (this study, median)
1σ conf. interval

Meeting 24/11/21

24 November 2021 16:00

Meeting with David and Laura 2:30

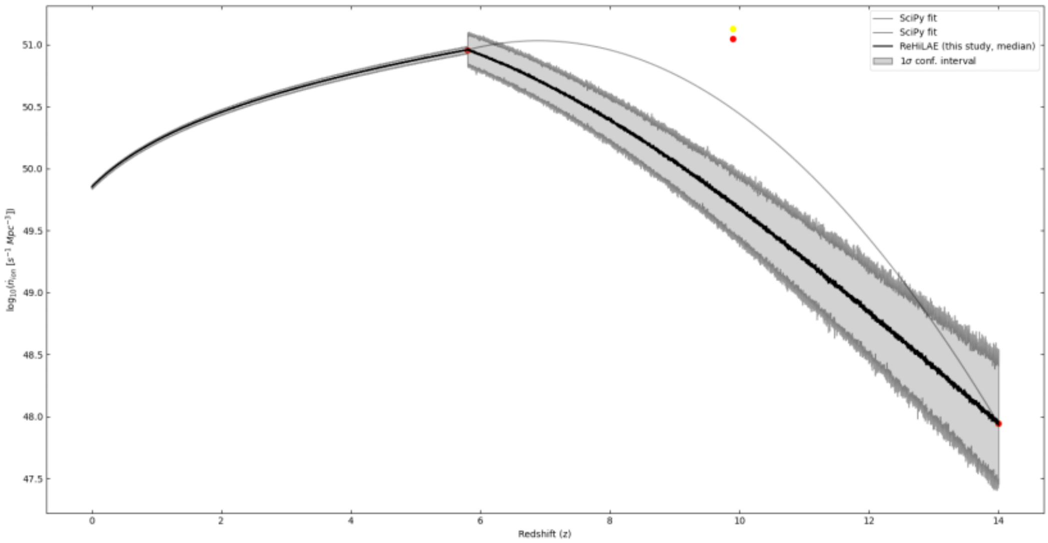
Essentially the feedback this week was on the right track but that I do not need to include so many different curves and I should likely focus on the quadratic simulations and possibly the linear simulations. Again quadratics are a priority and that now I should be looking to anchor my Quadratic sims at the peak of the rho graph z=5.8 point and then have it iterate over different crossing points.

Week 7/8

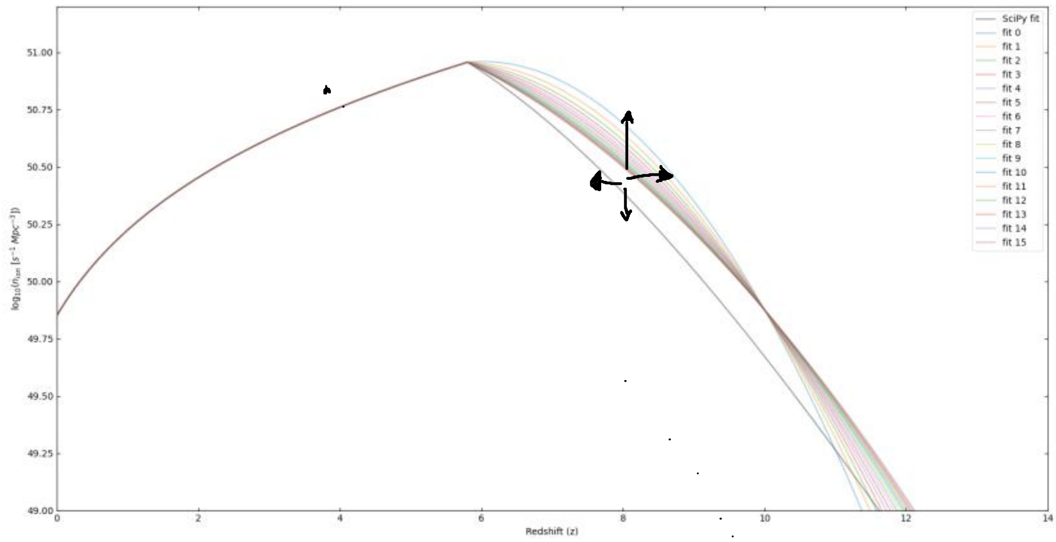
30 November 2021 13:00

So unfortuently what I did last week was very unproductive, All I did was just fit bowens data, David explicitly said to just plot some new curve that will be above the fit that is given by ReHilae, and just anchor it to the end of the ReHilae data.

After much trial I have successfully managed to anchor a quadratic function with 3 variables to Rho Lya and therefore Lya. Essentially the mechanism for anchoring any new quadratic can be fit relatively easily. Now I just need to somehow fit some of these values for Nion into the reionization simulation and see what I end up with.



I have even looped it in such a way that I can perturb values of the value of Bowens data given at a given redshift to give different curves that cross the bowens data at a specified point, I can probably also perturb values for the 2nd anchor point and whether it can go up or down, then I can just bin different redshifts of the anchor points, with crossing points

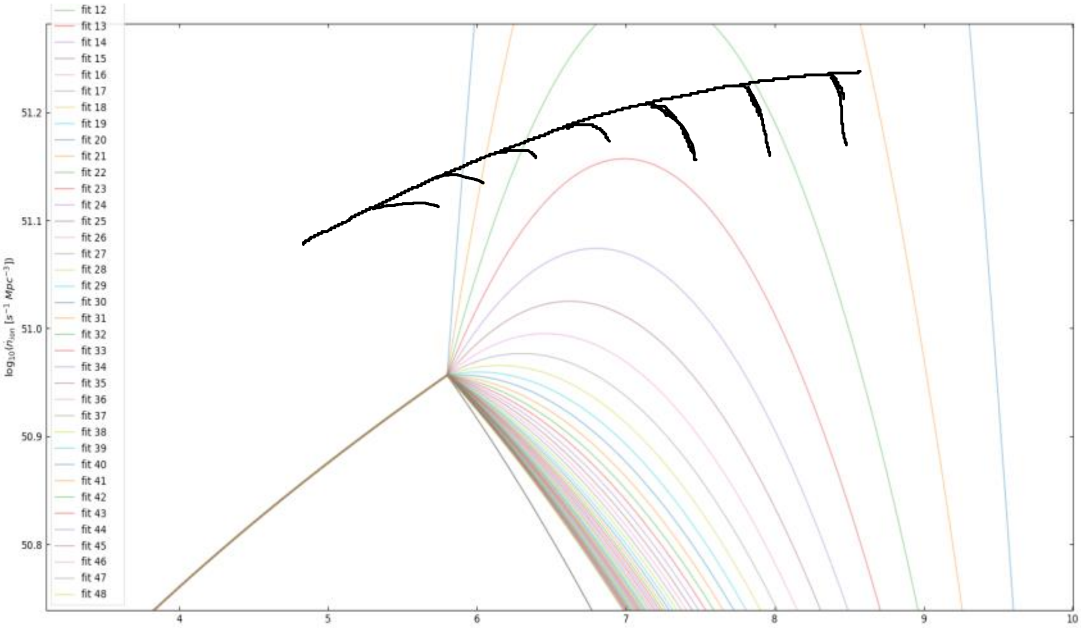


The Graph above shows how I can anchor a quadratic at different redshifts, so 5.8, 10 and then perturb values where it crosses the Rehilae data

I now just need to find a way to loop for different values of nion and also to use this method to plug in values of Q, I think I have a method for this.

I also do want to try this with cubics, and anchor two points and perturb another. I will talk to david about this as I am not sure.

Some quadratics go way above Nion as shown in the next graph



I was thinking of two possibilities, 1. is to cut the plots that go above the extrapolated Rho lya power law, or 2. let the p ower law take over until the curve is below the powerlaw

This would lead to much higher amounts of reionization at just above z=5.8 but beyond larger values it would be less, this is something to ponder or test.

Things I need to do for next time, assuming what I am doing is correct.

1. Fit some cubics and see how they react
2. Find a way to perturb values of nion and plot some curves from there
3. Find a way to plot nion for all the data I have onto the reionization python sim and see how it changes
4. Either remove large initial functions or fit them to an extrapolated powerlaw

Meeting 01/12/21

01 December 2021 16:30

Meeting with David and Laura and XGAL 2:30

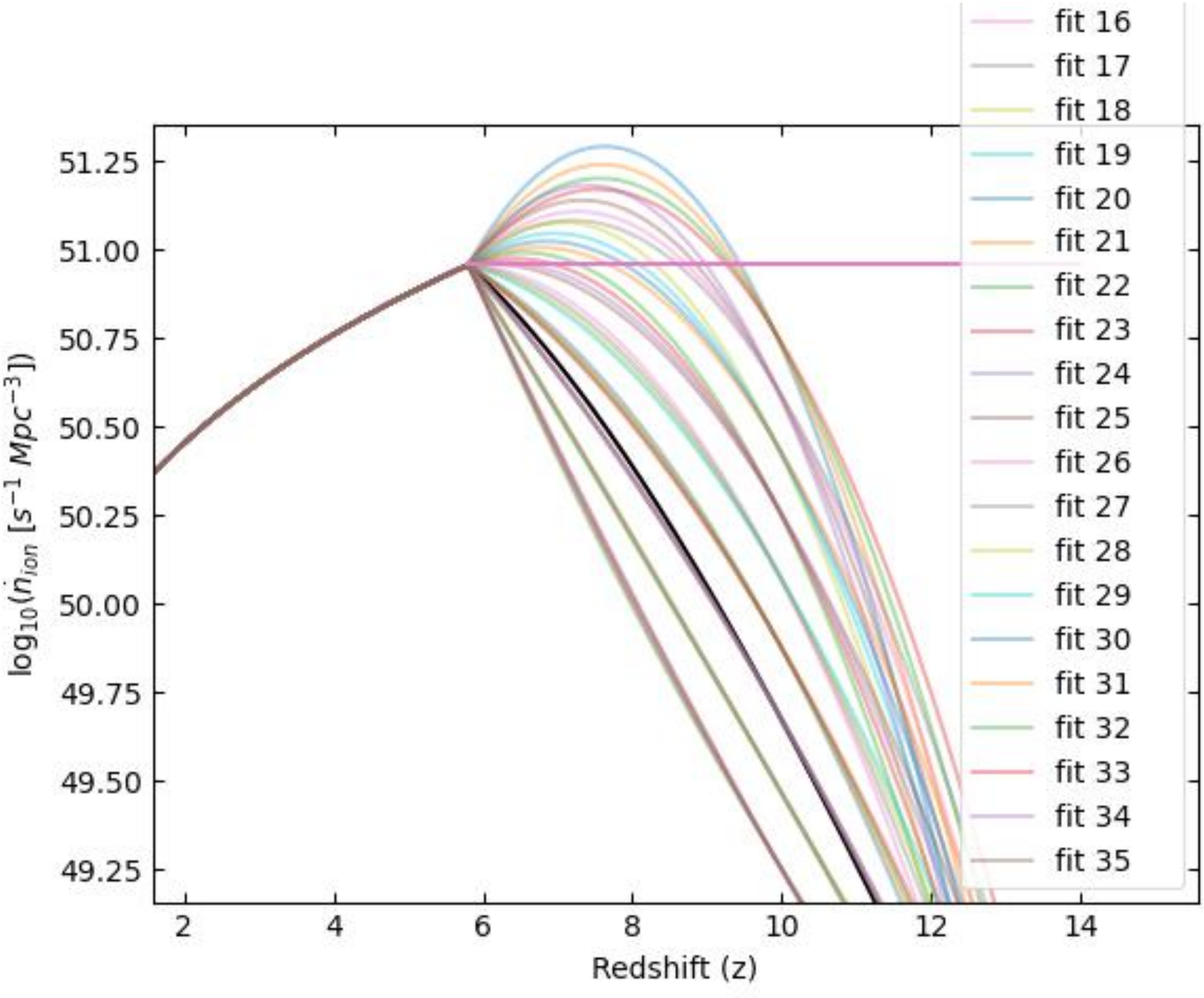
The meeting with David went well, instead of perturbing sims and have them be capped up until the point they surpass the cap, david recommended just cutting those graphs out of my simulation all together as we don't expect rho lya to be that high so it would only be quadratics with peaks below the max cutoff set by rehilae and davids data.

Week 8/9

07 December 2021 10:30

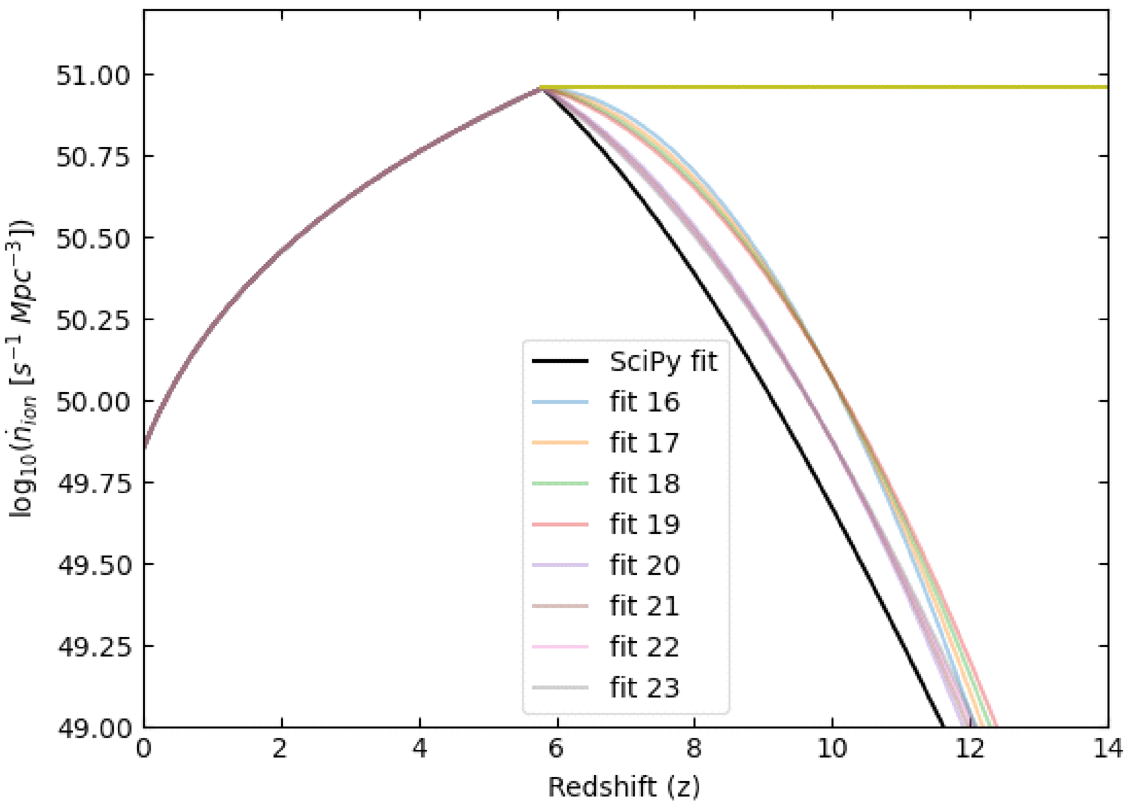
10:35
So this week I am mainly going to be trying to find a way of iterating twice over my code for my second anchor point, and making the curve check some criteria and implement my rho lya code into the mostly main sim to try and see what happens.

Iterating twice and using the boundaries 7.9, 12 for the first iteration and 13-14 for the second we het all of these potentially well fitting curves with the pink line representing the maximum value of rholya using the power law



[Tuesday 3:03]
I now need to find a way to get rid of the curves that either go to high, This was the value any curve which crosses should realistically not go over (I am taking this to be quite literal and any curve should not be allowed to go over the max value of the rho lya curve. We must also consider that this graph does not go below the bowens data too early and cut the curves that do this.

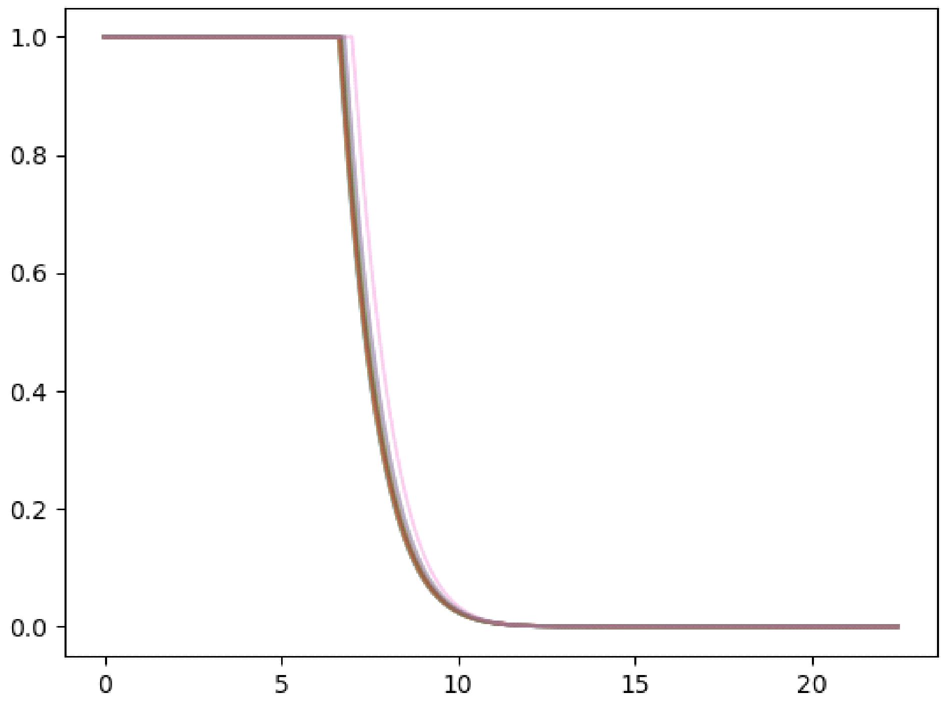
[Tuesday 4:35]
I managed to solve it using two nested if loops in a double nested for loop, not pretty but itll do.



Now I can iterate much much more without getting lots of graphs that cross thresholds I do not want

[Thursday - 1:00]
Now I need to see if I can fiddle with the simulation code and work out how to get my curve generator working for the integral

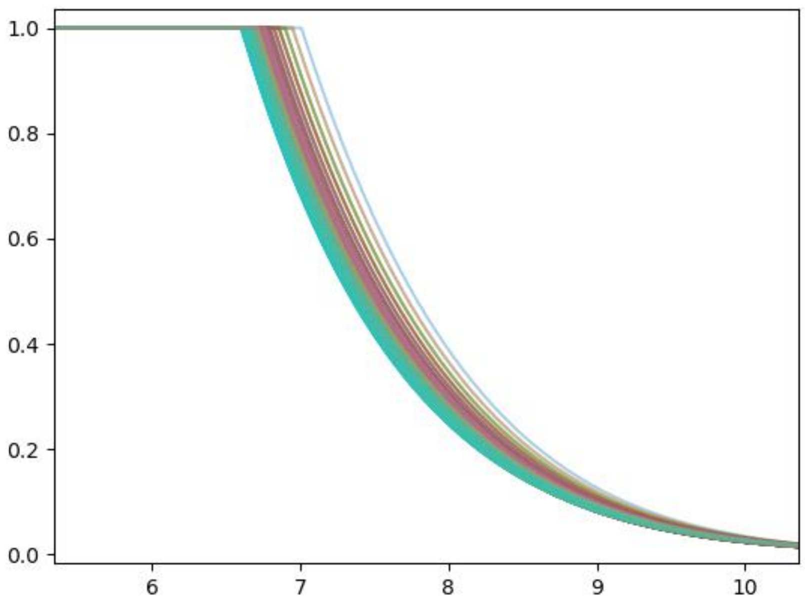
Got it to work with the sim code but just had to change a few bits from the rho lya code into the sim code, but it works surprisingly better than I thou



This graph however contains all of the curves from fig 1, these are unfiltered for whether they pass the nion/plya test.

So I need to find a way to filter them, this is a little bit trickier with this sim.

[Thursday 2:22]
Heres what more data looks like and how it changes the sim.

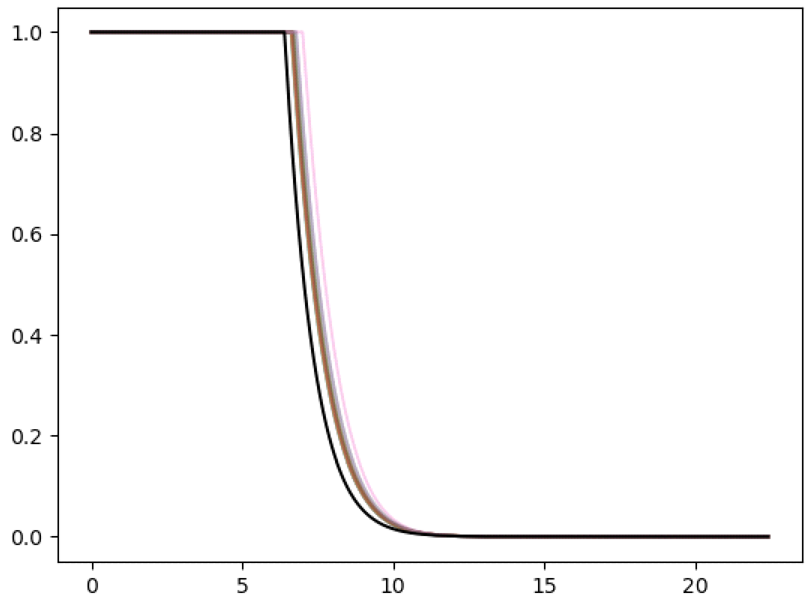


As you can see, small changes in the values for Plya can change the timing of reionization quite dramatically.

I still however need to find a way to get rid of the curves that are not supposed to be fit from this data set.

Unfortunately, the only thing I did not get done from last week was to fit cubics and see how they react instead, I might make that a goal for this week.

[Thursday 4:36]

1. Look at some cubics straight lines too and see how they vary
2. Get rid of the false curves from the sim data
3. Perhaps bin some values and get some results for reionization
4. Refitting with z=0
5. 

The graph above shows how we can move reionization forward with a few different curves. The black line shows the original formulae from rehliae

Meeting 08/12/21

08 December 2021 17:30

Meeting with David and Laura and XGAL 2:30

This week david told me to work on plotting new curves but instead anchoring two points (0,nion) and (5.8, peak nion) and then varying the final value to create new curves instead, also to try fit some straight lines and see how that works, and then finally cubics if I get a chance, then I can finally put these into my sim.

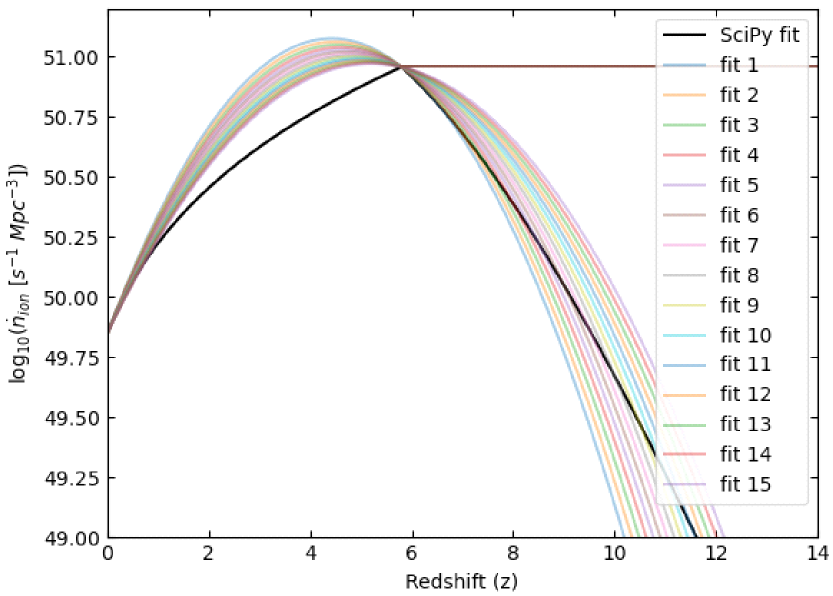
I also need to work on cutting down graphs that shouldn't be in the sim.

Week 9/10

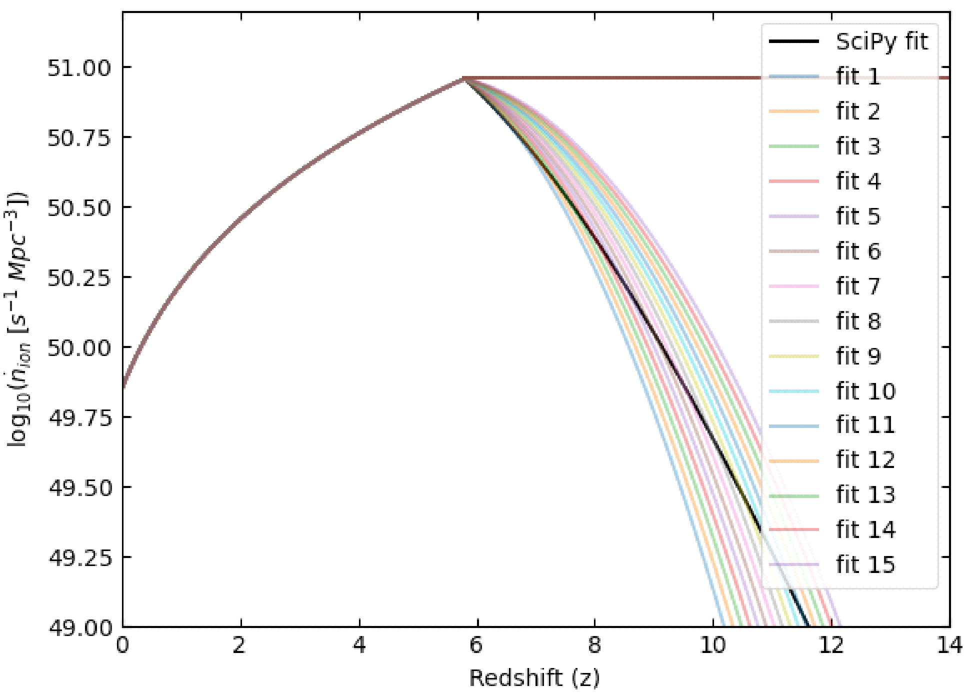
11 December 2021 11:00

Sat (11/12/21)

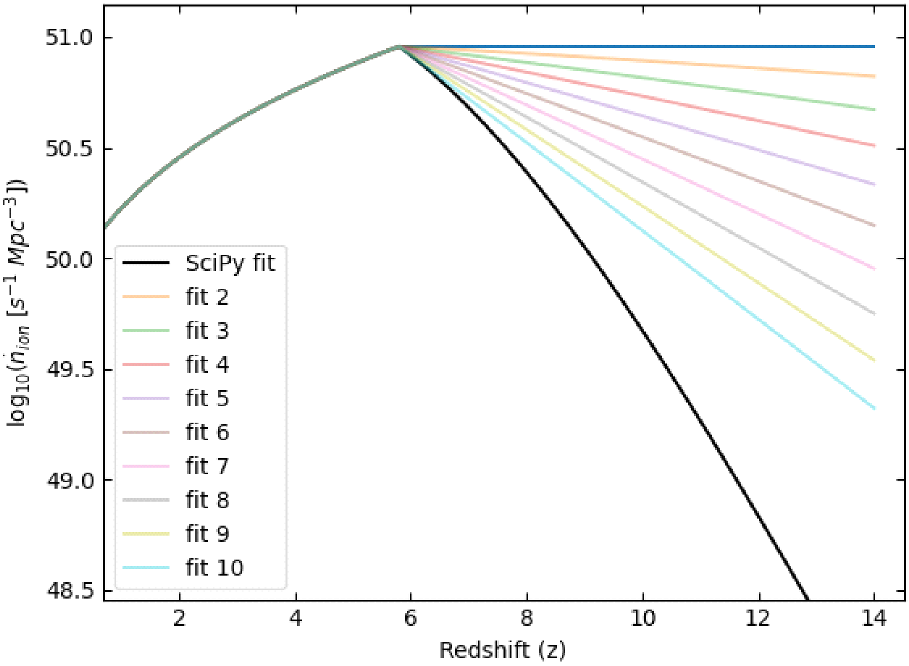
During this week I need to create quadratic sims that are anchored to 0,0, rehileas peak and then iterate over crossing points, rather than just anchoring at the rehilae peak and iterating, this will allow me to create much more evenly spaced curves. (11:00)



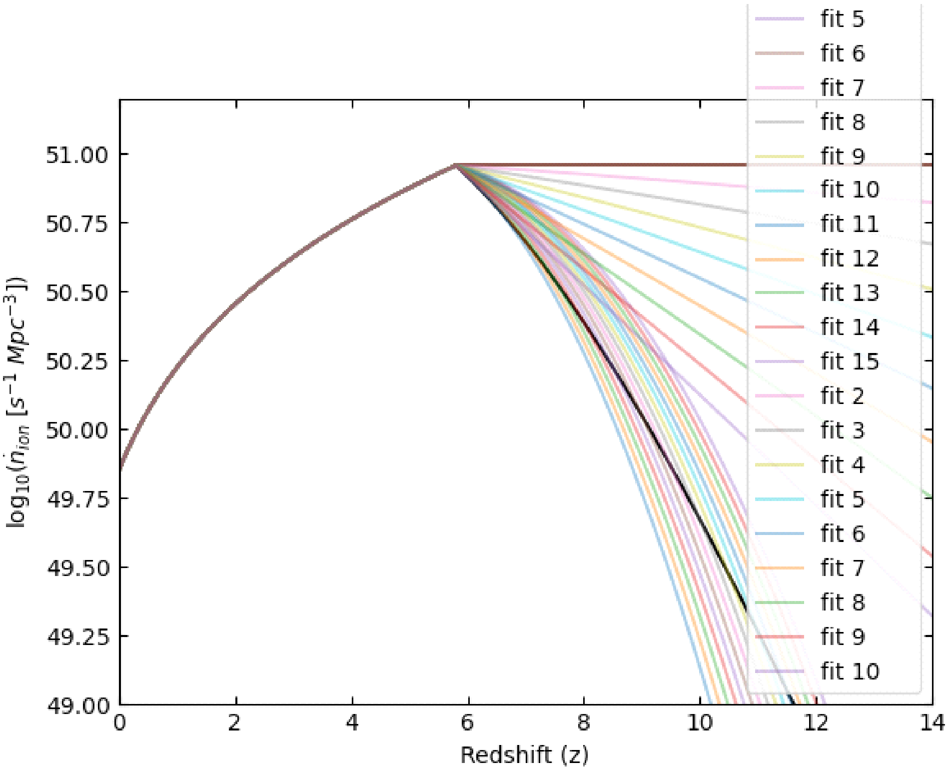
Now that I have my curves I need to cut them down at the point at rehilaes peak so they are only present for the right side of the graph. (13:30)



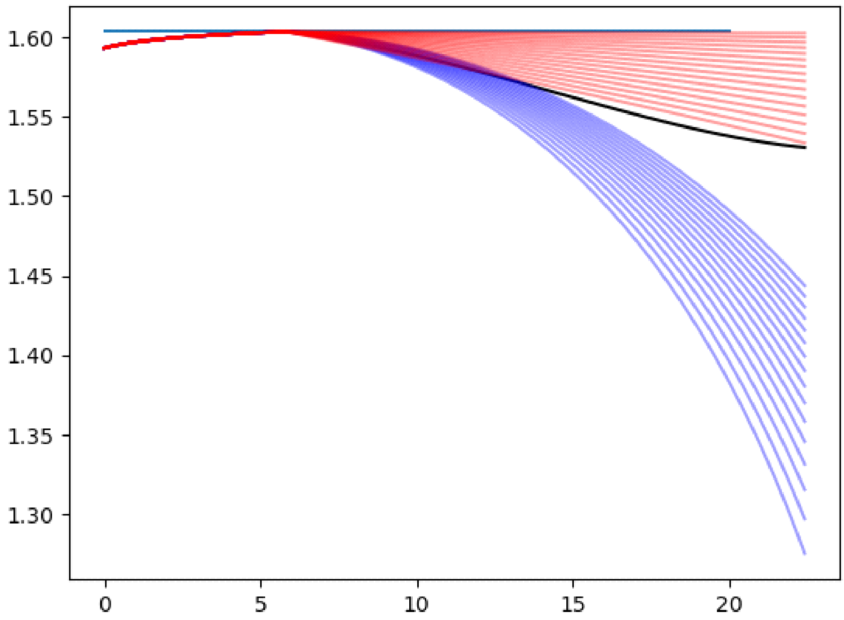
Now that the quadratics are done I can work on also fitting linear ones, these are much simpler. (15:00)



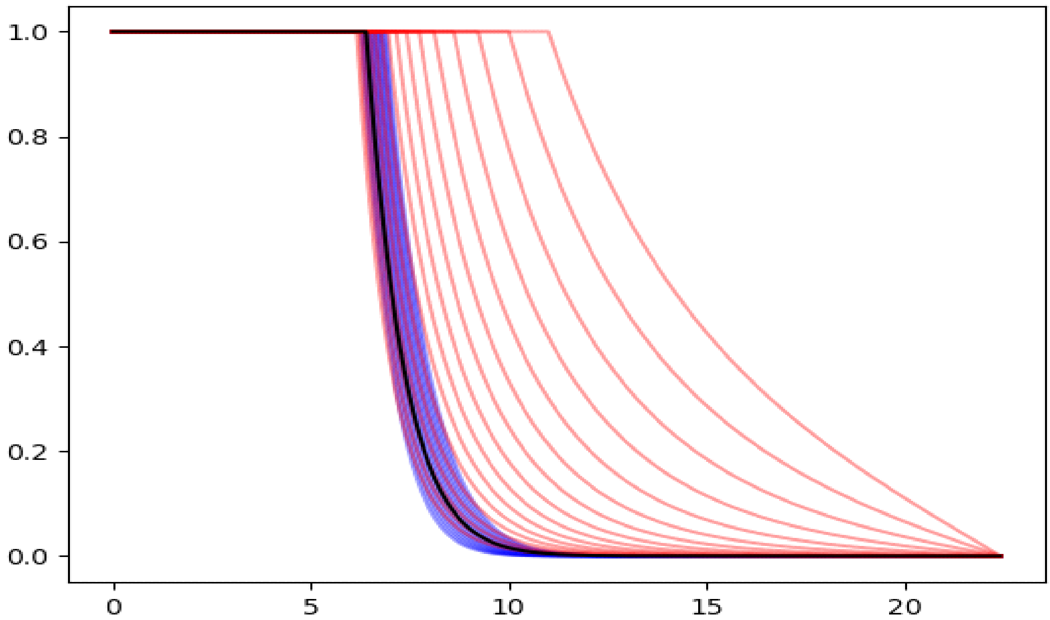
Here are both graphs combined (15:35)



Monday (13/12/21)
16:15
Finally I can simulate and when I do here are the outputs for Nion (First Graph), for Blue Quadratic Fits and Red Linear Fits



17:30
And also the reionization sim of fraction of ionised hydrogen is looking very good



Meeting 15/12/21

15 December 2021 17:00

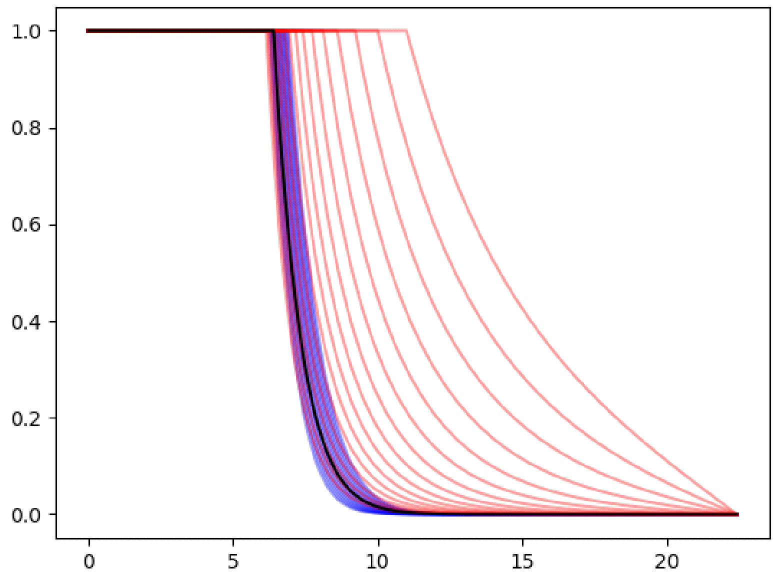
Meeting with David and Laura and XGAL 2:30

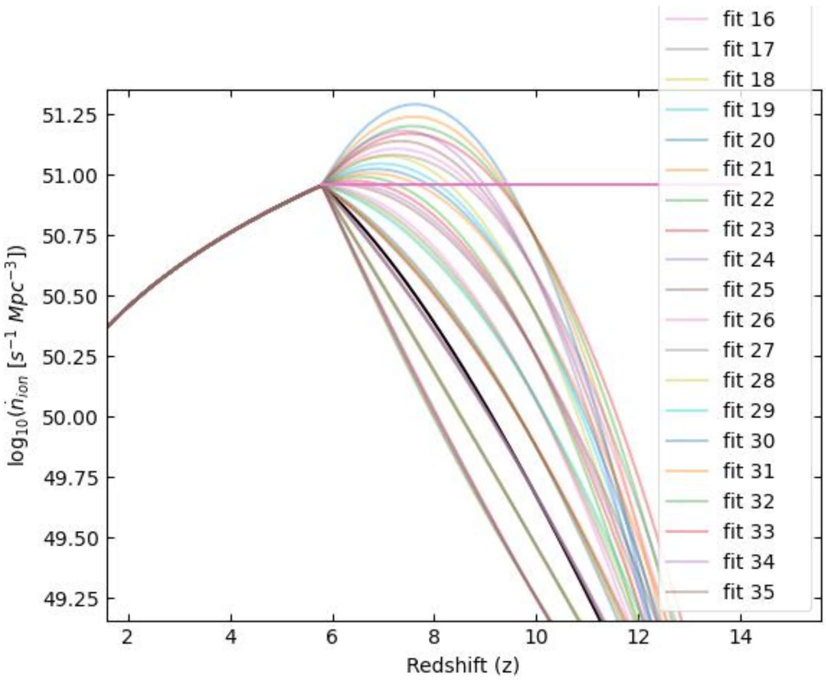
In my last meeting with David for the year, he was quite happy with the current graphs and how they are turning out and ideally said they just need data so I can start to cut down the amount of models that I have. I will also look to improve my graphing over the Christmas break

Week Christmas Break/10/11

07 January 2022 10:00

10:15
Here are my sims from last time, and whilst they were okay, they still needed a bit of work and many more iterations.



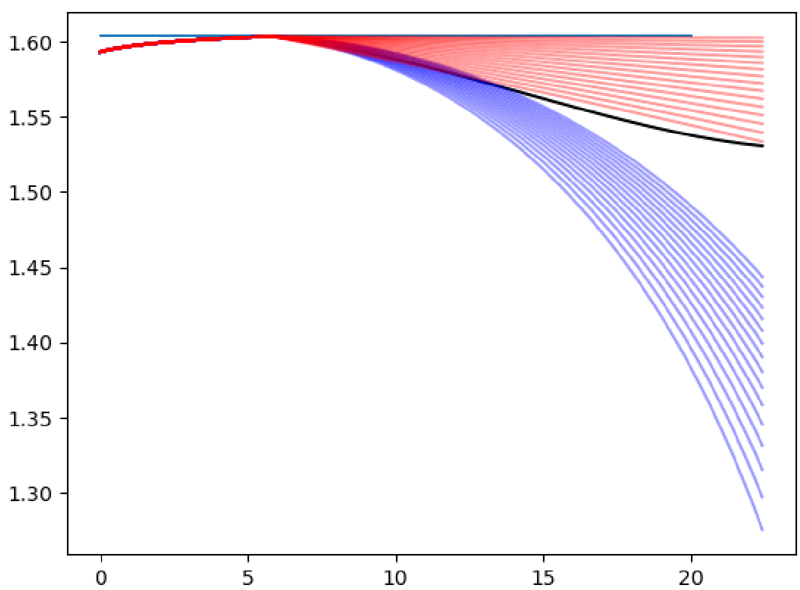


2:00 Here is a graph of my nion, as we can see it goes above and below our thresholds for bowens data therefore we need to introduce a cut, the way we do this is to compare at a certain value the discrete value of an iteration, and use that as a check, if its above the pink line or below the black at that point then it's a fail, if its above then it's a pass, we take the check to be somewhere near the apex of the curve as this is where we want the curve to decrease, but not too rapidly.

Here is the checks that you see in green

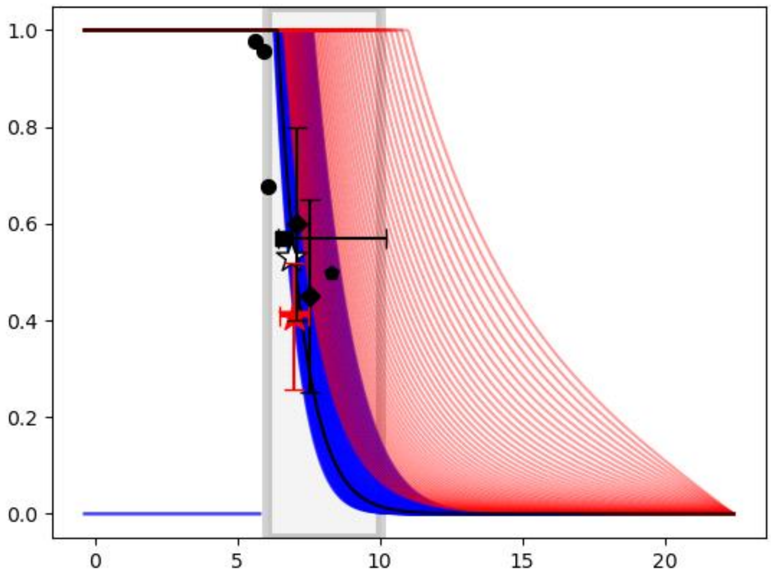
```
    Nion2 = nion2(6)*(2.938e+73)
    Nion3 = nion3(6)*(2.938e+73)
    if Nion2 > Nion1:
        List=[]
        ListR=[]
        AllPlots.append(main2(ts))
        for z in zs1:
            List.append(nion2(z)*(2.938e+73))
            ListR.append(P_Lya(z))
        AllPlotsN.append(List)
        AllPlotsR.append(ListR)
    if Nion3 > Nion1:
        List2=[]
        ListR2=[]
        AllPlots2.append(main3(ts))
        for z in zs1:
            List2.append(nion3(z)*(2.938e+73))
            ListR2.append(P_Lyalin(z))
        AllPlotsN2.append(List2)
        AllPlotsR2.append(ListR2)
```

The result is this new curve

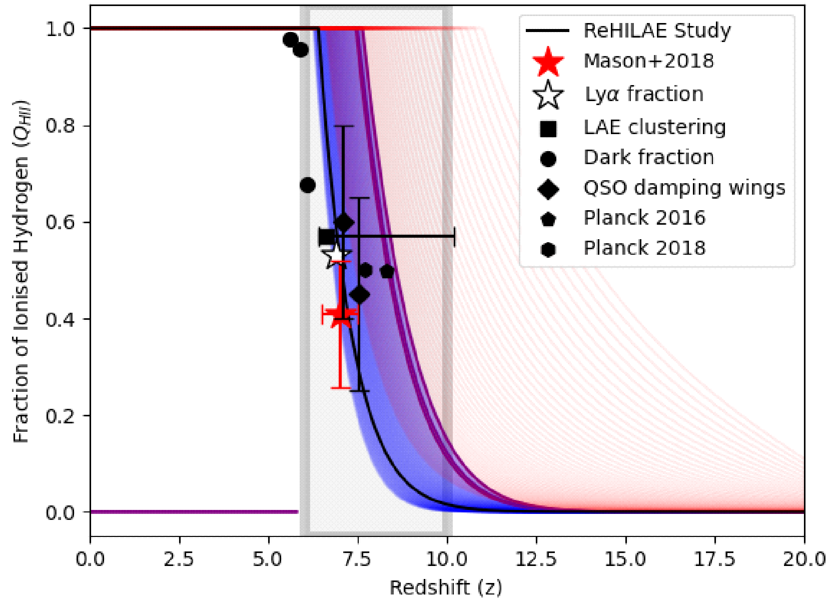


4:23 Now all we need to do is increase the iterations

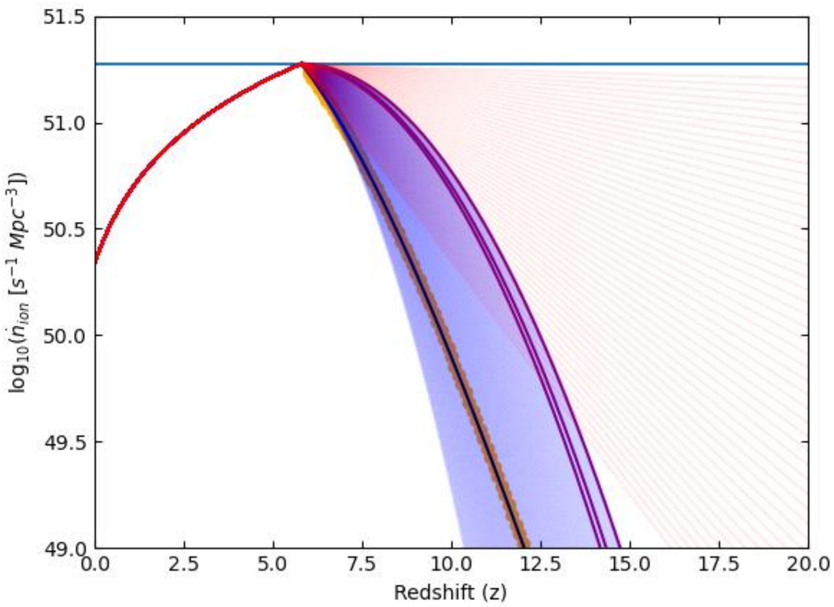
Increasing the iterations was trivial and only required me to decrease the step interval from 0.5 to 0.1 The result is shown below, I have also added in some data points to show

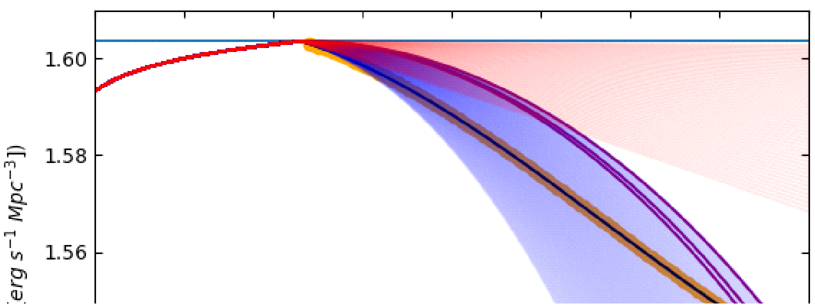


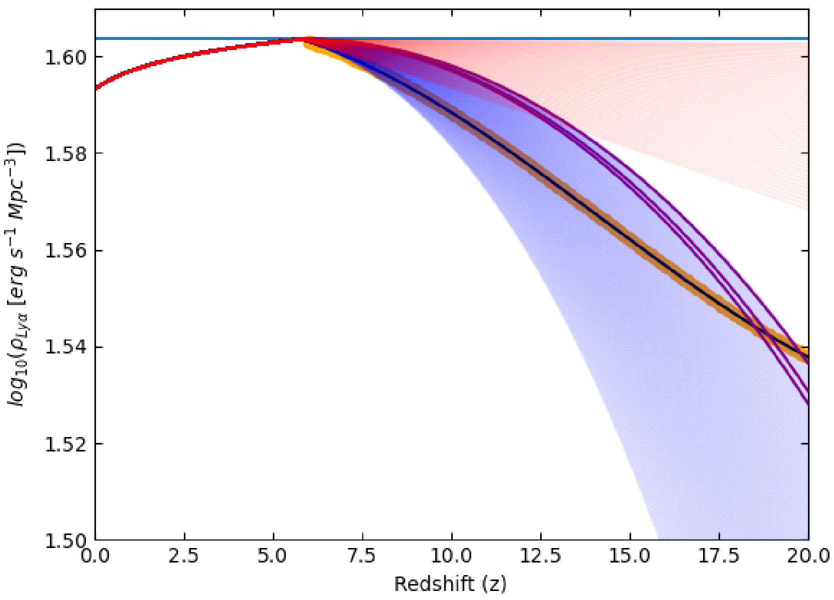
12/01/2022 1:15
Starting up the sims again I decided to add the legend and points back in from rehilaes data and I also decided increase the simulated period to redshift of 20 and extrapolating plya out to z=20 to see what sort of curves I could achieve.



2:30
I expected there would be very very early reionization and indeed I am correct when we look at the graph below, though even beginning at z=20 we find that reionization appears to not be too far off of the period of time in which we believe reionization occurred (z = 5.8-10), there are also some numerical issues with the purple curves that I need to investigate







3:05
Here are the Plya and Nion graphs of which both look very similar.

I also decided to change the colours of each fit to be set so that the graph was easier to read. Lastly I attempted a crude scatter of the crossing points between the black line and the blue lines for each iterated model.

During our meeting David seemed happy with the results and would like the models cut down for the far end of reionization as well as introducing data points to help cut down the amount of models.

Meeting 19/01/22

19 January 2022 16:00

Meeting with David and Laura and XGAL 2:30

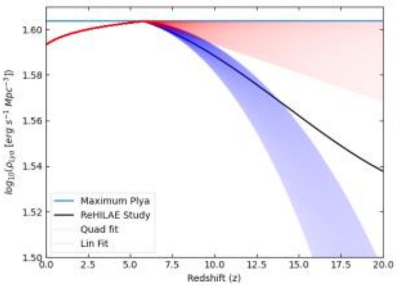
This week David said that I need to start cutting down models as this was very important and use parameters such as Chi Square to help cut down the data so that it matches the models, also to work on histograms of which models are doing well and which ones are not.

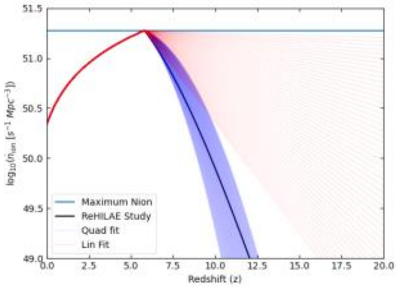
Week 11/12

23 January 2022 14:00

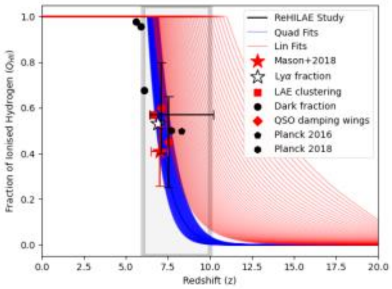
During this week I will mainly focus on cutting down the amount of curves that I had, I did this by reducing the number of iterations over the period of z-14 to 20.

I will also look for data to add to these graphs that are not from Rehlilae.



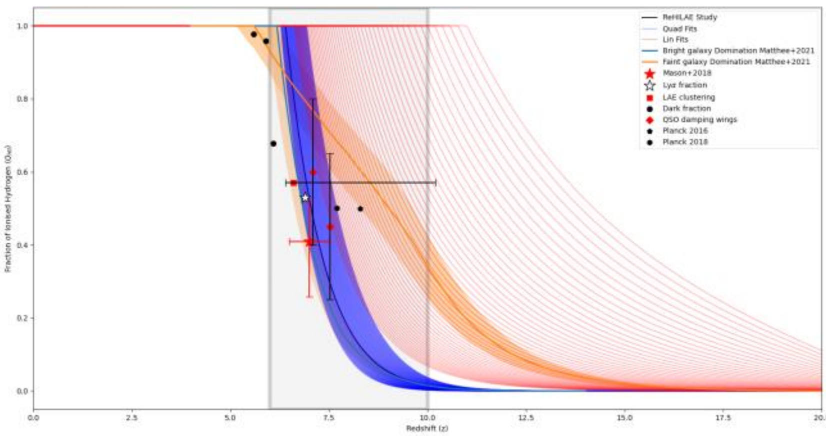


These are my graphs for nion and plya and as can be seen they cross only upto z=14 now.



This is the result of reionization, as can be seen its not particularly changed much although the number Of curves has reduced for both data sets.

What can be seen is that quad fitting lines up with many more data points than lin fitting does, this is to be expected.




```
z_F=a['F19']['z']
F_low=a['F19']['lower']
F_high=a['F19']['upper']
F_med=a['F19']['median']

z_N=a['N20_M1']['z']
N_low=a['N20_M1']['lower']
N_high=a['N20_M1']['upper']
N_med=a['N20_M1']['median']

plt.fill_between(z_N,1-N_low,1-N_high,color='tab:orange',lw=0,alpha=0.4)
plt.plot(z_N,1-N_med,color='tab:blue',lw=2,label='Bright galaxy Domination Matthee+2021')

plt.fill_between(z_F,1-F_low,1-F_high,color='tab:orange',lw=0,alpha=0.4)
plt.plot(z_F,1-F_med,color='tab:orange',lw=2,label='Faint galaxy Domination Matthee+2021')
```

I also got the data from Jorryts paper and his graph of reionization slope for faint and bright dominating galaxies, we can see that faint galaxies typically start reionization much earlier as they would be higher in number and population earlier on, they follow a sort of linear fit but one that accelerates and then slows at redshift of about 9. Bright galaxies on the other hand are more resemblent of "rapid" reionization but one that is slightly slower than any individual quadratic. I also have data points but they arent quite working yet, ill need to see how to use them

Meeting 26/01/22

26 January 2022 17:00

Meeting with David and Laura and XGAL 3:00

David saw my new graphs with the cut down version from z 20 to z 14 and whilst this was a step in the right direction to cut down graphs that were not very good, he proposed instead to actually do testing with data points such as Chi Square to get a goodness of fit with my simulations, and then cutting my sims down from there.

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I will need to do some research into Chi square to see how to calculate it and implement it into my code.

Talk with david on teams regarding Chi (Thursday 27th)

Week 12/13

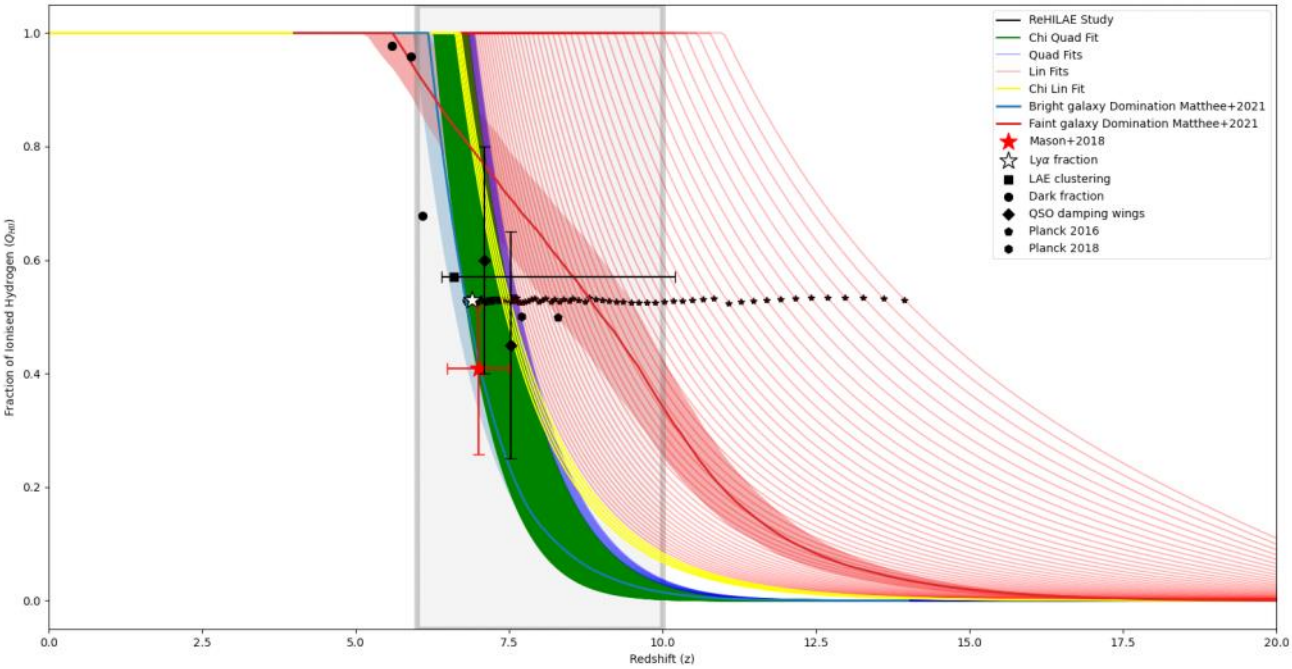
28 January 2022 15:30

This week I will be focusing on cutting down my models by using a chi square test of data points, so the first thing I need to do is to sample an area near the data points I wish to select as my reference reionization. I will first be using Lya Fraction as a test .

Lya Fraction

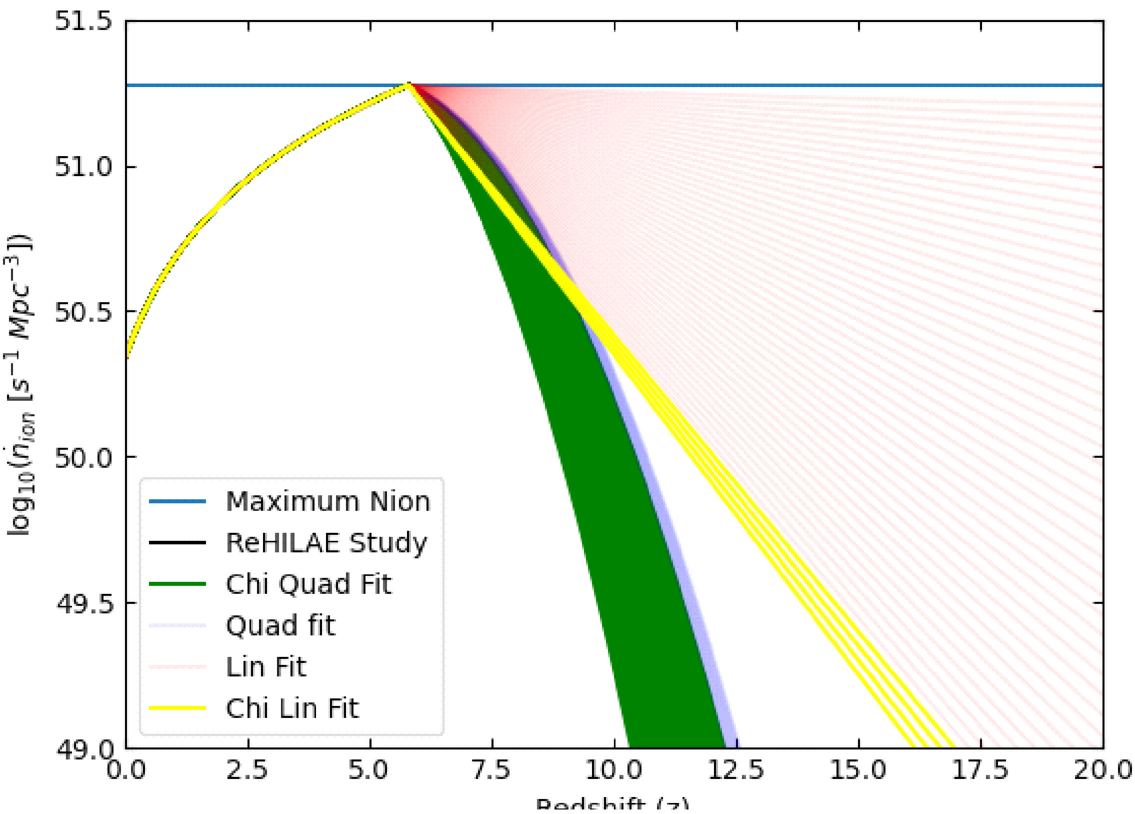
[6.894915254237289], [1-0.47044534412955463]

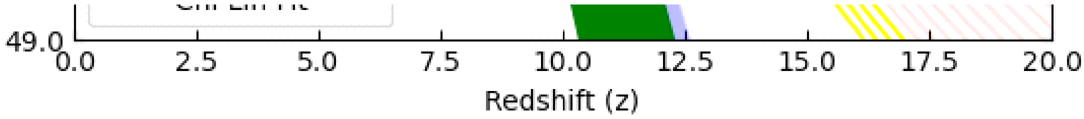
I need to sample the closest available data point to my data point so I used a closest to function that runs through the simulation data and finds the minimum value of (data point - sim point) and gives me the index of the list, I then use that index to extract the x data and use a Chi square where ChiSq= (Obs-Err)^2/Obs. Here is the resulting graph

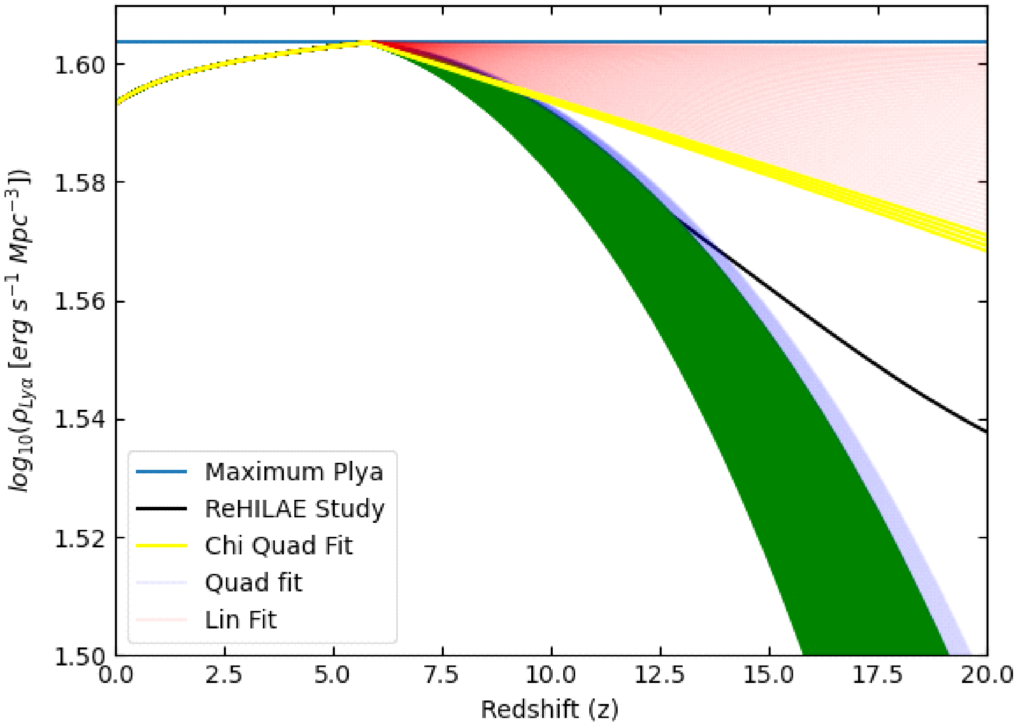


The data sampling seems to work okay however the points that are sampled are not at the same Y value and it seems that Chi for all my sims is too small, with this Chi has to be <0.05 to be picked up which is far too small and doesn't seem right

However my tracing is working for my Plya and nion graphs which is great which just traces back all of the selected graphs back through the inputted data, I just need to get some clarification on my main reionization sim from david in our next meeting (16:55)




49.0
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Redshift (z)


1.60
1.58
1.56
1.54
1.52
1.50
$log_{10}(\rho_{Ly\alpha}\ [erg\ s^{-1}\ Mpc^{-3}])$
Maximum Plya
ReHILAE Study
Chi Quad Fit
Quad fit
Lin Fit
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Redshift (z)

Meeting 02/01/22

02 February 2022 16:30

Meeting with David and Laura and XGAL 2:30

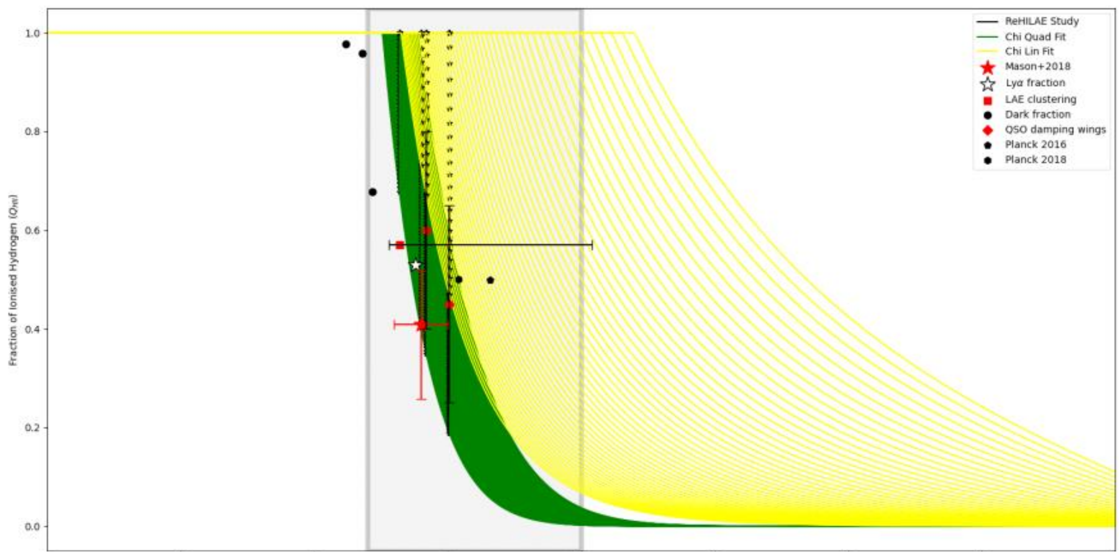
David was confused in the meeting about my graphs for CHI squared and noticed I am doing a number of things wrong, first of all

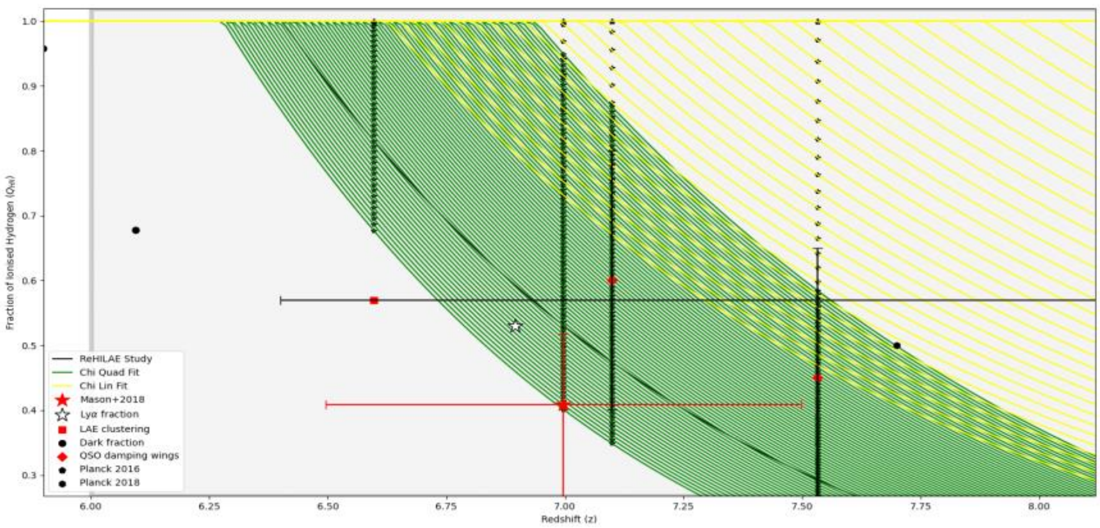
- I do not need to sample the closest point to the data point, I actually need to interpolate between the simulation for that exact value of the data point and then run Chi Square
- I also am sampling the wrong coordinates, Chi Square is a y data test always, so I need to calculate what Chi Square is from Y by interpolating at the same X value for all of my simulated data
- I am also apparently calculating Chi wrong as the very far out simulations should be cut out and Chi shouldn't be <0.05, It should be <1
- Lastly Chi is a summation over many data points, I cannot just use one data point to calculate Chi as that would mean its very broad, also using data points with no y err will not pick any simulation

Week 13/14

03 February 2022 13:30

Thursday 3rd 13:30
After the meeting with David about what I was doing wrong, I now know how to fix it. First thing first is to sample y values from a specific x value by interpolating, I will use pythons Interp1d command to do this for me.
I will also raise the expected value of chi so that it selects those to 1 and I will also perform a chi square for each point and summation over all of them to get my values. Here are the results

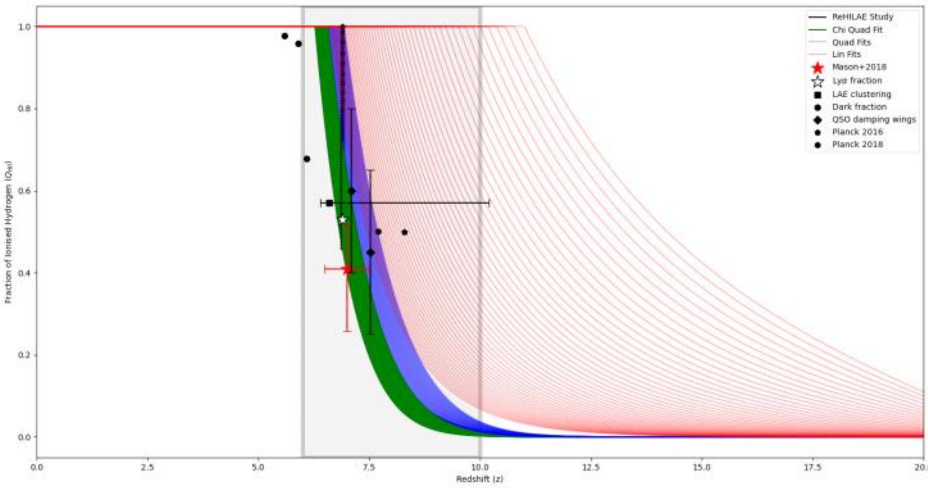


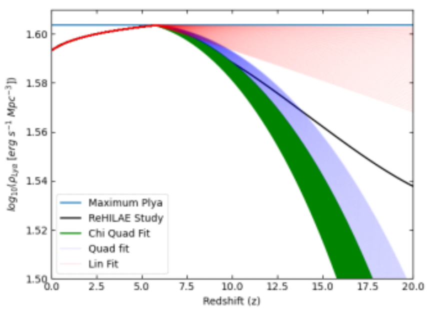


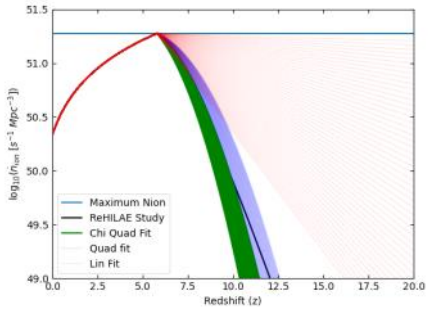
(15:25) Now although I am doing the summation over the 4 data points shown in red, the value for Chi is far far too low

Friday 4th of Feb

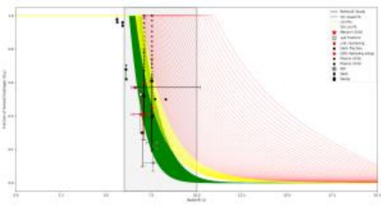
(11:00) I had a good chat with david about what was going wrong yesterday and it turns out I was completely miscalculating Chi Square by using (Obs - Expect)^2/ Obs when I should be Using ((Obs-Expect)/ExpectErr)^2. I will redo this and see how it pans out.

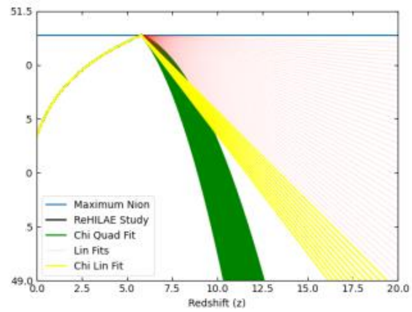


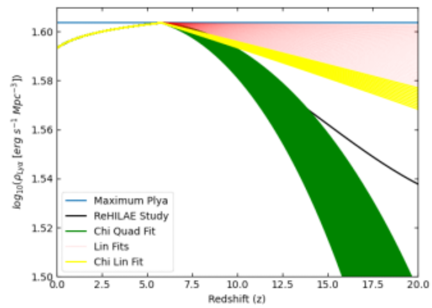




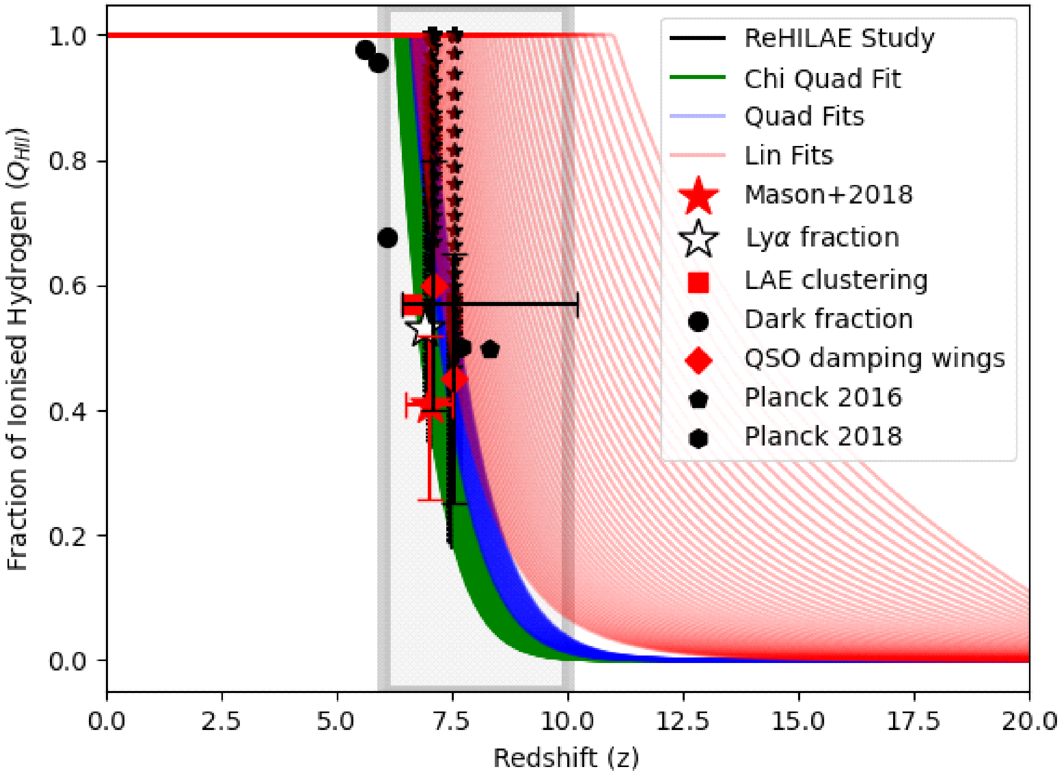
(12:15)This is how it works with one data point and it seems to be working suprisingly well, I will try again with 2 data points.





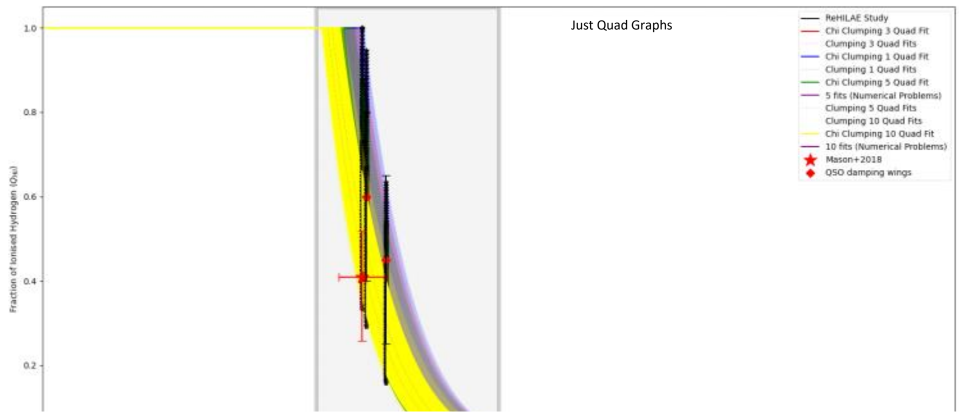


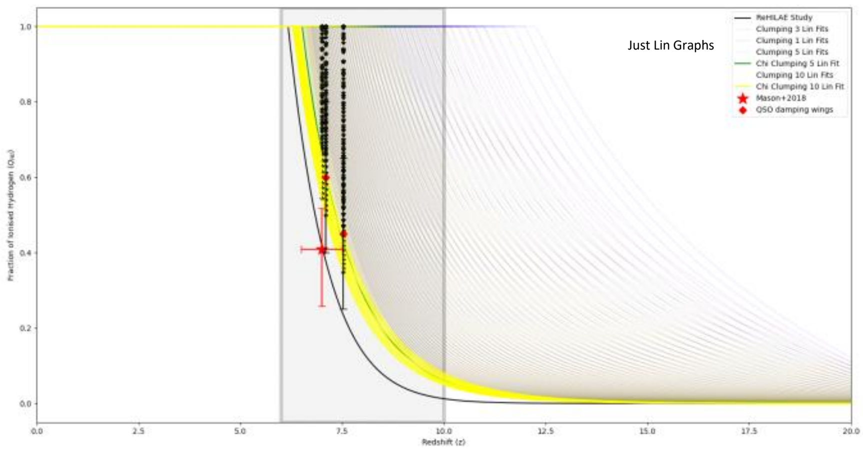
(12:50) And finally 3 data points

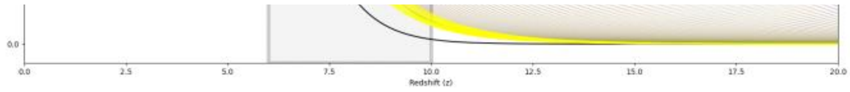


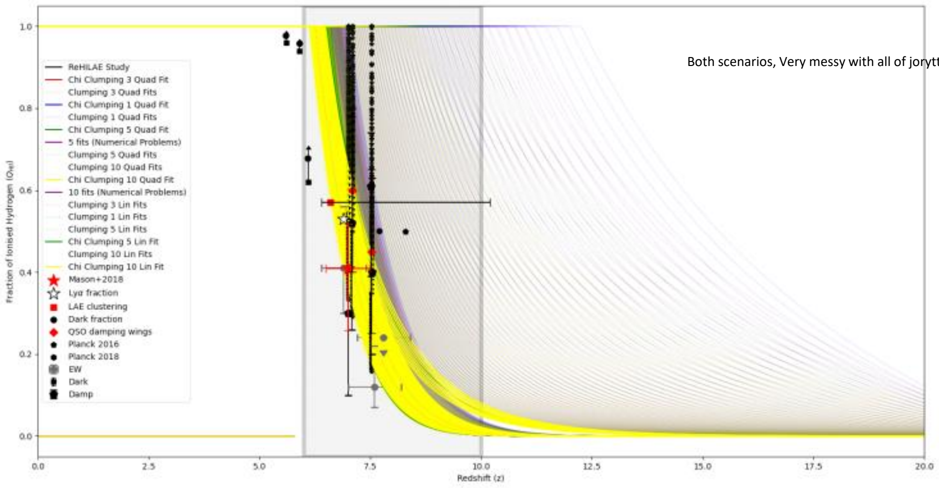
(2:00)This is the final result using 3 data points and the number of simulations is quite constrained. This looks to be a good graph. Next I need to create some histograms of the sims that are accepted, I will need to bin them however which means varying the initial parameters and saving the data.

Sunday 6th (12:20)I decided to vary the clumping factor as that seemed the easiest to do and test, So after running the Sims overnight for many hours and compiling the reionization data, here is what we got
C= 1,3,5,10









Both scenarios, Very messy with all of jorytts data and rehilaes

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Monday 7th (16:30) From these graphs it really seems as though higher clumping factors are better fits for reionization as it delays reionization quite substantially. Most of the Clumping factor 10 sims are accepted for Quad and Lin, Many Clumping factor 5 are accepted for quad but less for Lin, Many for Clumping factor 3 quad and none for lin, few for clumping factor 1 quad and none for lin. I will have to comprise this data into a histogram but this is now looking very good interms of progress on data collection.

Meeting 09/02/22

09 February 2022 17:30

Meeting with David and Laura and XGAL 4:00

Generally David was quite happy with how the graphs are now turning out and working and the next step is really to get my histograms as I have been putting them off for quite some time, I also need to refine Chi SQ to Chi Sq Reduced by changing my formulae to include the degrees of freedom in my plya calculation, for linear its just 1, for quad it would be 2 and so on.

I can also start mass data collection from the sims and start work on my report as soon as possible.