WEBVTT

1
00:00:00.000 --> 00:00:00.510
Floor Broekgaarden [she/her/hers]: Member.

2
00:00:02.730 --> 00:00:15.120
Floor Broekgaarden [she/her/hers]: As a member of Lego to the first attractions of gravitational waves I think that's a great thing to have in your PhD and she's actually also lead several of the detection and cosmology focus papers of Lego.

3
00:00:16.289 --> 00:00:29.910
Floor Broekgaarden [she/her/hers]: In our other work she particularly studies black holes that you can detect with Lego, and in particular the mystery behind why some of these black holes are very massive and what this tells us about our universe and.

4
00:00:30.570 --> 00:00:38.730
Floor Broekgaarden [she/her/hers]: Massive stars she received both the Sierra and the Einstein fellowship and is currently working at northwestern and she'll.

5
00:00:39.870 --> 00:00:44.310
Floor Broekgaarden [she/her/hers]: For sure tell us more about her work so yeah go ahead, my on my presentation.

6
00:00:45.900 --> 00:00:46.260
Floor Broekgaarden [she/her/hers]: Okay.

7
00:00:46.380 --> 00:00:53.610
Maya Fishbach (she): um yeah thanks so much for the invitation and i'm really looking forward to having a conversation with all of you.

8
00:00:54.750 --> 00:00:57.780
Maya Fishbach (she): So i'll just share my screen.

9
00:01:00.870 --> 00:01:19.620
Maya Fishbach (she): Hopefully, everyone can see that now great um yeah so today i'll be talking i'll be focusing on one aspect of the many lessons we've learned from my go in for go so far and that's this mystery of the biggest black holes that.

10
00:01:20.400 --> 00:01:31.020

Maya Fishbach (she): floor mentioned so just for a very quick introduction, we have these several gravitational wave observatories.

11
00:01:31.530 --> 00:01:42.330
Maya Fishbach (she): The ones that have been taking data so far, the two like oh detectors in the United States and the virgo detector the French, Italian detector.

12
00:01:42.900 --> 00:01:56.070
Maya Fishbach (she): there's also the Japanese detector call grow, which will be coming online soon, it was supposed to join, for the third observing run, which ended around the year ago.

13
00:01:57.150 --> 00:02:07.710
Maya Fishbach (she): But because of the pandemic things kind of got a little off schedule and then there's also lygo India, which should be joining the network in a few years.

14
00:02:08.580 --> 00:02:19.260
Maya Fishbach (she): So so far from these gravitational wave detectors are we have detected gravitational waves from around 50 mergers.

15
00:02:20.250 --> 00:02:33.660
Maya Fishbach (she): And the latest set of detections is published in this second gravitational wave transplant catalog or dw TC two and there were several papers that came out.

16
00:02:34.140 --> 00:02:39.840
Maya Fishbach (she): Last fall summarizing these detection so there's the catalog paper.

17
00:02:40.380 --> 00:02:50.160
Maya Fishbach (she): The population paper and the test of general relativity paper i'm the one I lead is the populations paper, and so a lot of the science i'll be talking.

18
00:02:50.730 --> 00:03:00.660
Maya Fishbach (she): to you about is in this paper and there's a lot in this paper that I won't talk about but i'm happy to if if anyone has questions.

19
00:03:01.650 --> 00:03:21.300
Maya Fishbach (she): So this is just a nice visual that my colleagues o'hara Dr made a showing all of these events, we detect the gravitational

waves from all of them, but we infer the masses of the two black holes and sometimes neutron stars, as they in spiral and merge.

20
00:03:22.650 --> 00:03:38.070
Maya Fishbach (she): And so, for each of the gravitational wave signals we detect the gravitational wave signal tells us something about the properties of that system so for black holes they're pretty simple.

21
00:03:39.630 --> 00:03:50.490
Maya Fishbach (she): They can be entirely described by their masses and their spins and so from the gravitational wasting know we learned something about the masses of the two black holes, the primary mass and one.

22
00:03:50.790 --> 00:03:57.300
Maya Fishbach (she): is just convention that it's the bigger of the two we learned about the spins of the black holes.

23
00:03:57.630 --> 00:04:07.860
Maya Fishbach (she): there's a spin magnitude, which says how fast they're spinning, but also some direction relative to the other black hole and relative to the orbital angular momentum.

24
00:04:08.400 --> 00:04:24.990
Maya Fishbach (she): And then we learned about the distance of the source from the detectors that depends on the luminosity distance and then some information about the position on the sky and the inclination and the polarization.

25
00:04:25.980 --> 00:04:31.650
Maya Fishbach (she): and measuring these parameters for each event is known as perimeter estimation.

26
00:04:32.430 --> 00:04:48.300
Maya Fishbach (she): just very briefly what we show for parameter estimation results as a posterior which by bayes theorem is related to the likelihood of getting that gravitational wave data stream in our detectors.

27
00:04:48.720 --> 00:05:02.940
Maya Fishbach (she): Given the source properties here i'm just saying masses time to some prior and the prior we use in the catalog paper, for example, it's just flat in the detector frame masses.

28
00:05:03.450 --> 00:05:12.060

Maya Fishbach (she): So this is just an example plot from that catalog paper that shows the analysis of every event individually.

29
00:05:13.050 --> 00:05:27.150
Maya Fishbach (she): These are just the new events from the third observing run in here that's showing the 90% posterior probability contours in total mass and mass ratio.

30
00:05:27.630 --> 00:05:39.450
Maya Fishbach (she): And you can see that some of these events are labeled on these are the ones that are special they had special, most of them had special papers.

31
00:05:39.960 --> 00:05:52.320
Maya Fishbach (she): That to go along with them like single event papers before the catalog release like gw 1905 21 which i'll talk about later is by far the most massive one, there are also some.

32
00:05:54.090 --> 00:05:56.220
Maya Fishbach (she): is likely, a binary neutron star system.

33
00:05:57.870 --> 00:06:12.600
Maya Fishbach (she): has very unequal masses of the mass ratio is founded away from one and 1908 14 is even more on equal masses and has a secondary object potentially in the lower mass CAP.

34
00:06:14.550 --> 00:06:19.950
Maya Fishbach (she): So all of these events are very interesting on their own.

35
00:06:21.870 --> 00:06:35.790
Maya Fishbach (she): back when we detected only like two events in observing run, we were very careful about every event and we loved each one individually, now we have so many events we can't even really remember all of their names.

36
00:06:36.780 --> 00:06:46.740
Maya Fishbach (she): But that's really exciting, because we can analyze them as a population and there's a lot to be learned from this population science so.

37
00:06:47.130 --> 00:06:59.190
Maya Fishbach (she): What we do is now rather than focusing on the individual masses of the black holes, we can introduce these population level hyper parameters that describe.

38
00:06:59.610 --> 00:07:07.620
Maya Fishbach (she): The distributions of the masses and spins and redshift of all of the events so as the most simple example that.

39
00:07:07.980 --> 00:07:16.650
Maya Fishbach (she): Within weibo and virgo we've been doing this, since the first observing Brian is just fitting a power law model to the mass distribution of black holes.

40
00:07:16.980 --> 00:07:30.630
Maya Fishbach (she): Where now there is some probability of seeing a mouse and I depends on the power law slope, and now, rather than being interested in what the masses of the individual buchholz are we're interested in the value of this power loss loop alpha.

41
00:07:31.770 --> 00:07:49.830
Maya Fishbach (she): And when we do this, we have to take into account measurement uncertainty and selection effects so it's a little bit tricky i've written down the likelihood here and I won't go too much into it, but feel free to ask me more detailed questions about the analysis method.

42
00:07:51.030 --> 00:07:59.340
Maya Fishbach (she): So here i've just listed all of the astrophysical lessons and the gravitational wave data that we have in this.

43
00:07:59.910 --> 00:08:12.000
Maya Fishbach (she): Populations paper which you can find here, so you can see we're starting to learn a lot about the masses the spins in the merger rate and its evolution with redshift.

44
00:08:12.930 --> 00:08:26.970
Maya Fishbach (she): But for this talk i'll just be focusing on this first point, which is about the black hole mass spectrum and what happens above 45 solar masses.

45
00:08:29.040 --> 00:08:43.110
Maya Fishbach (she): So i'll try to answer these three questions it for the rest of the talk, but I just wanted to pause and see if there are any any questions so far about the introduction.

46
00:08:48.690 --> 00:08:49.800
Morgan Elowe MacLeod: Maybe.

47
00:08:50.820 --> 00:08:55.650
Morgan Elowe MacLeod: We should also, I mean maybe we should keep going and.

48
00:08:57.960 --> 00:09:01.410
Morgan Elowe MacLeod: sort of discuss discuss when we get to a little.

49
00:09:02.760 --> 00:09:03.300
Maya Fishbach (she): sounds good.

50
00:09:03.750 --> 00:09:31.950
Maya Fishbach (she): um yeah so for the first point is where where R Ly goes a black holes, and this was a paper that I wrote with my PhD advisor Daniel holt's in back in 2017 just looking at the first four detections from Lego in virgo we noticed that there was something weird going on.

51
00:09:33.000 --> 00:09:42.810
Maya Fishbach (she): In that the bigger the black holes, you have the more sensitive our detectors are to them.

52
00:09:43.890 --> 00:09:51.720
Maya Fishbach (she): But all of the bought clothes, we observed in the first two observing runs were down here below around.

53
00:09:53.040 --> 00:09:58.350
Maya Fishbach (she): 40 solar masses and individual this is showing the total massive below around at solar masses.

54
00:09:59.520 --> 00:10:12.630
Maya Fishbach (she): And then we didn't detect any black holes bigger than that, even though the sensitivity of our detectors increases, so we did this population analysis and we found that.

55
00:10:13.260 --> 00:10:25.800
Maya Fishbach (she): The systems must actually be rare and the underlying population if the gravitational wave signals from them should be so loud, but we don't have any in our data, maybe they're just absent in the universe.

56
00:10:26.850 --> 00:10:45.300
Maya Fishbach (she): And so we did this fit to the black hole masses, we observed, we fed a power law with sharp cut offs at low mass and high mass and we found that this maximum mass where the mass distribution cuts off was around 40 solar masses.

57
00:10:46.350 --> 00:10:52.710
Maya Fishbach (she): And the data was consistent with comment from this distribution, and so we.

58
00:10:54.180 --> 00:11:17.880
Maya Fishbach (she): So this is showing like that posterior on the maximum mass parameter, and you can see that we measured it to be 42 solar masses plus 15 minus 5.7, and this is just compared to the masses the individual posteriors with those uninformative priors of the masses of the other blackpool's.

59
00:11:19.080 --> 00:11:24.000
Maya Fishbach (she): And so you can kind of see like where this measurement is coming from.

60
00:11:25.260 --> 00:11:30.150
Maya Fishbach (she): All of the black holes we've observed are consistent with having mass.

61
00:11:30.210 --> 00:11:31.980
Maya Fishbach (she): below this maximum mass.

62
00:11:32.310 --> 00:11:53.070
Maya Fishbach (she): Even though some of them with the uninformative priors might have support at higher masses, but that is we argued that that is just a statistical fluctuation that this is really the maximum the maximum mass of the black holes is somewhere within this posterior in the dashboard.

63
00:11:55.320 --> 00:12:00.840
Maya Fishbach (she): So, in the next part of the talk i'll i'll describe what this means.

64
00:12:01.860 --> 00:12:05.460
Maya Fishbach (she): And how the latest discoveries of big black holes fit into it.

65
00:12:06.840 --> 00:12:09.720
Maya Fishbach (she): Are there are there any questions on the first part.

66
00:12:12.030 --> 00:12:33.840
Maya Fishbach (she): Okay um so yeah So this was a really interesting observation or finding, because this was entirely consistent with

theoretical predictions that have been going back to the 1960s about stellar evolution and, in particular there's this prediction that.

67
00:12:34.920 --> 00:12:51.990
Maya Fishbach (she): When the when you have stellar cores that are in the range 40 to 120 so our masses they that star undergoes what's called a pulsation all or just a parent's stability supernova and leaves behind.

68
00:12:52.680 --> 00:13:04.770
Maya Fishbach (she): either no blackhole remnant at all, or has these really violent pulses where it sheds enough mass so that the final black hole remnant is below this 40 solar mass cut off or so.

69
00:13:05.940 --> 00:13:15.420
Maya Fishbach (she): So this was a pretty firm theoretical prediction for stellar evolution that would just apply to any black holes that are formed from stellar collapse.

70
00:13:16.080 --> 00:13:30.240
Maya Fishbach (she): Of course, if you have a black hole that's not for in terms dollar collapse there's no need for it to obey this mass gap, you could have black holes that are for insurance all a black hole is they can be in the mascot no problem.

71
00:13:31.350 --> 00:13:39.840
Maya Fishbach (she): And then, and so this is this is opens up this cool new science, that we can do with gravitational wave observations because.

72
00:13:40.110 --> 00:13:53.550
Maya Fishbach (she): Clearly, our observations are telling us something about the parents stability mascot and what we measure of the black hole masses can help us resolve some theoretical uncertainties about parents stability.

73
00:13:54.120 --> 00:14:01.590
Maya Fishbach (she): So one example is uncertain nuclear physics location of this mass gap depends on.

74
00:14:02.850 --> 00:14:14.220
Maya Fishbach (she): Most primarily rob farmer found in this paper this one particular nuclear reaction rate and so, if you vary the value of this nuclear reaction rate by a couple of.

75
00:14:14.610 --> 00:14:28.650

Maya Fishbach (she): Standard deviations you can vary, where the mass gap starts and also where it ends there have also been a series of papers by Juno crew and as Dan McDermott and JEREMY 16.

76
00:14:29.490 --> 00:14:45.450
Maya Fishbach (she): That talk about how beyond standard model of physics can also very wear this mask ap is, and so the black hole masses that we detect with gravitational waves can also probe this beyond standard model of physics.

77
00:14:47.430 --> 00:15:03.930
Maya Fishbach (she): And so that was all very nice very clean picture from the first two observing runs but then, in September, the Lego and virtual collaboration we announced that there was this new detection.

78
00:15:06.450 --> 00:15:24.480
Maya Fishbach (she): And this was very popular with the press, because it's this like giant black hole, the primary was around 85 solar masses and it's also exactly contradicts what we thought was true, which is that there's this massive gap there So what is this black hole doing there.

79
00:15:25.860 --> 00:15:38.010
Maya Fishbach (she): And so just for context, this is similar to that plot I showed earlier, where in the blue dashed lines, we have the maximum mass that we measured from the first catalog.

80
00:15:38.610 --> 00:15:48.120
Maya Fishbach (she): And, and that was this number that was around 40 solar masses, this was the most massive event from the.

81
00:15:48.840 --> 00:15:58.170
Maya Fishbach (she): From that first catalog and now we have dw 1905 21 the primary message is here in orange in the secondary mass in.

82
00:15:58.590 --> 00:16:12.060
Maya Fishbach (she): Green, you can see that the secondary mass has some overlap with this maximum mass posterior so okay like maybe the secondary mass is 40 solar masses and it's below that gap.

83
00:16:12.420 --> 00:16:31.650
Maya Fishbach (she): But the primary mass has no overlap with this maximum mass, so it is inconsistent with our inference from before, and that is what makes it so surprising observational Lee based on our previous observations and also based on theory.

84

00:16:33.030 --> 00:16:47.730
Maya Fishbach (she): And so, just very quickly, I wanted to mention this other fun interpretation what from what might be going on is that, actually, since what we measure in the previous slide I showed the.

85
00:16:48.240 --> 00:16:59.640
Maya Fishbach (she): posteriors on the two component masses well we actually measure well is the total mass like the our influence on the primary mass in the secondary and master very correlated.

86
00:16:59.970 --> 00:17:10.410
Maya Fishbach (she): And you can see that in the purple here is just the 2d posterior on primary and secondary mass, and that means that if we actually assume that the secondary masses below with a gap.

87
00:17:11.550 --> 00:17:22.380
Maya Fishbach (she): We say well it's probably more likely that we have that this system contains a black hole, like the previous black holes we've seen rather than two brand new black holes.

88
00:17:22.980 --> 00:17:35.100
Maya Fishbach (she): So we move that black hole below the gap with a different choice of prior, then the primary mass actually gets shifted to have considerable considerable support above the gap.

89
00:17:35.910 --> 00:17:54.300
Maya Fishbach (she): So that that is just one possibility it's hard to tell to just play these prior games with one event but definitely on a population level, we can start to see whether there really is a population of black holes above that gap so i'll be exciting i'll skip this slide for now.

90
00:17:55.440 --> 00:18:05.670
Maya Fishbach (she): But it's not just dw 1905 21 i'm there are other big black holes in the second gravitational wave catalog.

91
00:18:06.480 --> 00:18:19.950
Maya Fishbach (she): That are bigger than anything we saw in the first two observing runs so again here in blue this is that maximum mass that we measured from the first two observing runs around 40 solar masses.

92
00:18:20.460 --> 00:18:32.940
Maya Fishbach (she): And in these dashed and dotted lines here, you can see some of the primary masses that we've observed in the third observing run that are.

93
00:18:33.510 --> 00:18:42.720
Maya Fishbach (she): Pretty intention with this maximum mass that we thought was true, and so, if we now measure what the maximum mass is.

94
00:18:43.050 --> 00:18:57.750
Maya Fishbach (she): With the third observing run, we got this red curve here, even if we take out 1905 21 we got this being one here, so the maximum mass definitely seems to be increasing, and now that we have new detections.

95
00:18:59.460 --> 00:19:04.410
Maya Fishbach (she): And so, this kind of brings up a lot of questions.

96
00:19:05.940 --> 00:19:14.760
Maya Fishbach (she): There are several possible interpretations one is that maybe these most these more massive black holes that we've now observed in.

97
00:19:15.420 --> 00:19:33.930
Maya Fishbach (she): The third observing run are inside the mask the mask actually starts at 40 solar masses these black holes are bigger than 40 solar masses, maybe they're made in a different formation channels like they're made from smaller black holes through hierarchical mergers or something else.

98
00:19:35.250 --> 00:19:49.830
Maya Fishbach (she): Maybe the mask APP starts at higher masses than previously thought and maybe the reason we thought there was a cut off at 40 is no there's actually not a cut off at 40 it's a taper that starts at 40.

99
00:19:50.250 --> 00:20:02.070
Maya Fishbach (she): And there's some rate of black holes above that taper but it's just smaller and that's why we're only seeing them now is that there aren't as many of them out there.

100
00:20:03.600 --> 00:20:22.620
Maya Fishbach (she): And part another interpretation, maybe he is that the there is a subpopulation of black holes above 40 but that evolves with redshift so either there's a sharp cut off that varies with redshift.

101
00:20:23.640 --> 00:20:37.140

Maya Fishbach (she): Or maybe these these black holes are just found at higher redshift and that leads me to the last part which is the evolution of black hole masses across cosmic time.

102
00:20:38.610 --> 00:20:53.220
Maya Fishbach (she): And so, this is just another way of looking at the black hole masses we just add another dimension, and we see maybe this extra piece of information there redshift can help.

103
00:20:53.580 --> 00:21:15.630
Maya Fishbach (she): me disentangle these different possibilities for what's going on with these big black holes and so here, this is the these 90% probability contours, and these are actually all like each one of these is a contour even though they're all overlapping of the primary mass versus the redshift.

104
00:21:16.710 --> 00:21:29.430
Maya Fishbach (she): And what you can see is that in blue here we have the ones from the first catalog and an orange from the venue events from the second catalog and the.

105
00:21:30.180 --> 00:21:44.310
Maya Fishbach (she): New events that we've observed in the second catalog are actually probing higher redshift because the detect the detectors became more sensitive in the third observing run were able to see black holes too hot further distances.

106
00:21:45.660 --> 00:21:55.140
Maya Fishbach (she): And so it makes sense we're looking at a higher redshift but that's also where all of these biggest black holes are.

107
00:21:55.530 --> 00:22:07.650
Maya Fishbach (she): So does this indicate that we're actually observing a different population, like the mass distribution is different at higher redshift than it is at the low redshift super observing before or.

108
00:22:08.580 --> 00:22:15.660
Maya Fishbach (she): Is it just that we're now probing a larger volume in the universe, and so we're able to see the rare events.

109
00:22:17.370 --> 00:22:32.880
Maya Fishbach (she): And so, this is from a recent paper that my collaborators and I put on the archive just last month and and we actually looked into doing this population analysis, so we.

110

00:22:33.270 --> 00:22:54.690
Maya Fishbach (she): assume that there are some mass distribution either a truncated model, so this just power law with a sharp cut off or a broken power law model which allows for this more gradual taper at some break mass and we allow these to evolve with redshift and we we fit for that.

111
00:22:55.740 --> 00:23:10.020
Maya Fishbach (she): So the here, this is showing the 99th percentile of the primary mass distribution is a function of redshift and you can see that if we assume that the mass distribution has a sharp cut off.

112
00:23:10.590 --> 00:23:22.110
Maya Fishbach (she): This is this blue evolving truncated model that cut off must increased with redshift, and so the black hole the most massive black holes.

113
00:23:22.500 --> 00:23:38.610
Maya Fishbach (she): must become more massive at earlier times in the universe done today, but if there is more of a taper in the mass distribution like there is some breaks in the power law have shown an orange here and we allow that to evolve with redshift.

114
00:23:39.570 --> 00:24:01.500
Maya Fishbach (she): It there's some hints that yes, maybe it does, but it's definitely not as strong and it's also definitely consistent with not evolving with redshift, so this is what I just said in words and another way of looking at this is.

115
00:24:02.700 --> 00:24:28.590
Maya Fishbach (she): Looking at the rate of mergers, both low mass mergers with primary masses below 45 solar masses and the heavier mergers with primary masses above 45 solar masses looking at that rate across redshift and so you can see that if if the mass distribution really does evolve with redshift.

116
00:24:29.790 --> 00:24:34.590
Maya Fishbach (she): Then it's possible that it that's in orange here.

117
00:24:35.850 --> 00:24:47.820
Maya Fishbach (she): it's possible that it the most the rate of the most massive mergers is very low average of zero, but then increases to a few.

118
00:24:49.320 --> 00:24:54.720
Maya Fishbach (she): To a few mergers per cubic ago parsecs per year, as we go out in Fred shift.

119
00:24:55.890 --> 00:25:07.830
Maya Fishbach (she): But another thing that is is cool is that we, we do have evidence, even if the mass distribution doesn't evolve with right ship that their overall rate evolves with redshift.

120
00:25:08.610 --> 00:25:19.410
Maya Fishbach (she): So if the mass distribution doesn't evolve and the rate at all masses must evolve with redshift and that starts to tell us interesting things about like the time delay, distribution and start formation rate.

121
00:25:20.460 --> 00:25:31.740
Maya Fishbach (she): And another thing that I I briefly mentioned, I just want to say that people are definitely looking into this is that maybe there are multiple formation channels going on, so I just talked about.

122
00:25:32.160 --> 00:25:41.640
Maya Fishbach (she): Looking at what the redshift information can tell us in more detail about the mass distribution and the history of the.

123
00:25:42.150 --> 00:25:54.900
Maya Fishbach (she): biggest black holes, but we can also look at spins to add more information, and so the spin distribution at the highest masses compared to the lowest masses might tell us.

124
00:25:55.380 --> 00:26:05.580
Maya Fishbach (she): If there really is a different formation channel going on, and the one primary way to do this is by looking at the spin magnitudes.

125
00:26:06.600 --> 00:26:23.340
Maya Fishbach (she): So this is showing a plot from actually my first paper from Grad school where here in pink you see the spin distribution that we expect to have for black holes that are formed from.

126
00:26:23.790 --> 00:26:36.810
Maya Fishbach (she): Earlier mergers and there has been a lot of theoretical work recently to that suggests that maybe black holes board from stellar collapse they're actually very slowly spending so that would be zero on this plot.

127
00:26:37.770 --> 00:26:49.770

Maya Fishbach (she): So seeing if the the black holes that are bigger maybe within this mass gap tend to also be spinning that around 70% of the maximum spin.

128
00:26:50.340 --> 00:27:07.950
Maya Fishbach (she): That could help disentangle these different channels to and there's i'm just showing there's one, there are other papers but there's one paper by a Grad student at northwestern chase kimball that was posted recently that that looks at this analysis also.

129
00:27:08.970 --> 00:27:18.150
Maya Fishbach (she): Okay, so this is my last slide and then hopefully we can have some discussion so just summarizing.

130
00:27:19.590 --> 00:27:27.660
Maya Fishbach (she): I talked about where our light goes big black holes and the first evidence for this mask up in the black hole mass spec drum.

131
00:27:29.370 --> 00:27:41.940
Maya Fishbach (she): And then talking about some of the theoretical interpretations from that and the latest discoveries of big black holes, which are inconsistent with a sharp cut off in the mass distribution.

132
00:27:42.780 --> 00:27:54.660
Maya Fishbach (she): Maybe we've even observed a black hole on the far side of them ascap and then I talked about looking at the black hole mass distribution and its evolution with cosmic time.

133
00:27:55.320 --> 00:28:09.540
Maya Fishbach (she): Maybe that can tell us something about the underlying physics of of what's forming these big black holes and then just to say that about how and why of this is.

134
00:28:10.830 --> 00:28:17.070
Maya Fishbach (she): is looking at this provides clues about how the black holes are actually made.

135
00:28:18.060 --> 00:28:23.760
Maya Fishbach (she): there's still some feature in the mass distribution or 40 solar basses so we can't just like throw away.

136
00:28:24.180 --> 00:28:32.970
Maya Fishbach (she): The theory stellar evolution theory that predicted this parents ability mascot this definitely still something going on in the mass distribution.

137
00:28:33.330 --> 00:28:46.590
Maya Fishbach (she): is just more complicated than we thought from the 10 the first 10 detections and so connecting this back to supernova theory will.

138
00:28:47.130 --> 00:29:05.730
Maya Fishbach (she): will help us say something about uncertain nuclear physics, maybe particle physics and also there's a cool application that we can use this feature in the mass distribution to measure cosmological parameters which I didn't go into but i'm happy to if anyone has questions about that.

139
00:29:10.860 --> 00:29:12.330
Morgan Elowe MacLeod: Wonderful Thank you so much.

140
00:29:14.970 --> 00:29:16.290
Floor Broekgaarden [she/her/hers]: yeah Thank you so much Maya.

141
00:29:16.950 --> 00:29:19.710
Floor Broekgaarden [she/her/hers]: This is a great talk it's also interesting I.

142
00:29:20.160 --> 00:29:24.690
Floor Broekgaarden [she/her/hers]: I got I received a lot of questions so thanks everyone and feel free to still pose questions to me.

143
00:29:25.080 --> 00:29:32.820
Floor Broekgaarden [she/her/hers]: And i'm i'm really happy or it's very interesting to see that a lot of them are actually have also about these riches and cosmology so.

144
00:29:33.210 --> 00:29:41.880
Floor Broekgaarden [she/her/hers]: And since that's also a topic that you discuss a lot I think that's great, especially since we have so many people here that are interested in the cosmological distributions.

145
00:29:42.570 --> 00:29:51.990
Floor Broekgaarden [she/her/hers]: So, actually, I think I want to first ask Jesse hon to maybe unmute and ask this question because I think it's a kind of a good first question, to start with yeah.

146
00:29:53.940 --> 00:29:54.750
that's night.

147
00:29:55.770 --> 00:30:11.820
Jesse Han: Thank you, someone for the Doc Maya that was great my question was what is the Lego selection function when it comes to plotting the primary mass versus redshift and how are you modeling the likelihood like is that a plus on point process what what kind of modeling is going on here.

148
00:30:18.450 --> 00:30:18.720
Jesse Han: I think.

149
00:30:20.790 --> 00:30:21.030
Jesse Han: Oh.

150
00:30:21.090 --> 00:30:23.370
Maya Fishbach (she): yeah sorry i'm classic.

151
00:30:24.930 --> 00:30:27.450
Maya Fishbach (she): Right, so we actually.

152
00:30:28.500 --> 00:30:38.940
Maya Fishbach (she): So this is kind of a rough idea of what that selection looks like this shaded region here are the.

153
00:30:39.960 --> 00:30:47.370
Maya Fishbach (she): Are the systems that would be follow this simple calculation of a signal to noise ratio and.

154
00:30:48.210 --> 00:31:00.630
Maya Fishbach (she): What we actually do so, basically, you can see, like at low masses, we can only observe them out to like redshift point two, and not the largest masses, we can see them out to like.

155
00:31:01.140 --> 00:31:22.920
Maya Fishbach (she): higher than redshift one in the third observing run and then at even larger masses they get the frequencies of the gravitational wave get red shifted, and so we start to lose sensitivity, because they now merge outside of our band.

156
00:31:24.300 --> 00:31:36.330
Maya Fishbach (she): And so what we actually do is we have injections, so we inject like the gravitational wave signal for given masses.

157

00:31:36.930 --> 00:31:46.830
Maya Fishbach (she): We have like a broad distribution over masses spins and redshift that we inject into data from the detector is and then.

158
00:31:47.220 --> 00:32:00.840
Maya Fishbach (she): run the search pipelines, on which are the ones that pick out these signals to begin with, and then we look at the false alarm rate that the injections are found with and.

159
00:32:01.590 --> 00:32:11.850
Maya Fishbach (she): and see if that's above threshold or below threshold and then that goes into that second part is this which I didn't explain it all.

160
00:32:12.450 --> 00:32:29.310
Maya Fishbach (she): But it's great you asked about it, so this is so we model, this is basically a in homogeneous post on process likelihood except the form, I showed here is marginalizing over the the overall rate.

161
00:32:30.360 --> 00:32:37.800
Maya Fishbach (she): And so, these probabilities are just like like this probability here is normalized.

162
00:32:38.880 --> 00:32:56.310
Maya Fishbach (she): Over i'm wanting to do you integrate this over i'm one of them to it'll 321 so it doesn't have the overall rate in it, but, basically, this is the selection effect term which we have, which is the fraction of the technical systems in the population.

163
00:32:57.420 --> 00:33:06.630
Maya Fishbach (she): And so, just very simply, if you have this depends on like your population hyper parameter.

164
00:33:07.650 --> 00:33:19.320
Maya Fishbach (she): So for very negative power loss slopes, for example, there's now a much stronger preference in the population for low masses.

165
00:33:19.680 --> 00:33:38.010
Maya Fishbach (she): Now, means that this number will be smaller because i'll detect fewer systems, out of that population and so that serves to like up wait that value in the likelihood and and that that's how we like account for the selection effects.

166
00:33:43.920 --> 00:33:47.760

Floor Broekgaarden [she/her/hers]: i'm pretty I know, do you want to ask your question I think that's great.

167
00:33:49.380 --> 00:33:51.240
Juliana Garcia-Mejia: Thank you, I think this is great.

168
00:33:51.330 --> 00:33:56.610
Juliana Garcia-Mejia: um so I you can put this in your conclusions slide but.

169
00:33:57.120 --> 00:34:10.740
Juliana Garcia-Mejia: Do you think you could comment, a little bit more on the stellar implications of these increasing miles gap with redshift expected because primordial stars are more massive Is there something related to medalists at or is there more complicated picture going on.

170
00:34:12.240 --> 00:34:12.990
Maya Fishbach (she): yeah that's.

171
00:34:13.230 --> 00:34:15.660
Maya Fishbach (she): a really great question and I.

172
00:34:15.750 --> 00:34:18.330
Maya Fishbach (she): don't know the answer to it.

173
00:34:19.830 --> 00:34:29.580
Maya Fishbach (she): I just I like try to keep up with with the literature, but I don't think there's consensus so basically we so.

174
00:34:30.810 --> 00:34:52.320
Maya Fishbach (she): The we expect like the black hole mass distribution to depend on the metal a city of the stars that day formed from so if anything at higher redshift lower medalists at ease we'd expect more massive black holes.

175
00:34:53.730 --> 00:35:09.600
Maya Fishbach (she): But there's also, I think there are a lot of uncertainties about what the distribution of medalist cities is at a given redshift like even at low redshift so you have some pockets of the universe, with very low medalists at.

176
00:35:10.080 --> 00:35:16.080
Maya Fishbach (she): And this is further complicated because when we observe a black hole.

177
00:35:17.220 --> 00:35:33.630
Maya Fishbach (she): merger we don't observe it at the redshift that it formed there is some delay between the formation of the star wars which might be low model, a city and then the formation of the black hole is and the in spiral in the merger and so.

178
00:35:34.920 --> 00:35:46.440
Maya Fishbach (she): It could be that that time, those that time delay distribution is very broad and so maybe some black holes that we observed at redshift zero we're actually formed at redshift six.

179
00:35:47.550 --> 00:35:48.900
Maya Fishbach (she): And so it's.

180
00:35:49.920 --> 00:35:55.410
Maya Fishbach (she): In that respect, I think the the theoretical predictions are complicated.

181
00:35:56.460 --> 00:36:12.780
Maya Fishbach (she): And then another thing is if we're actually looking at like the location of the parents stability mask APP so i'm like there's like in these plots it so in.

182
00:36:13.890 --> 00:36:17.190
Maya Fishbach (she): rob farmers paper about this.

183
00:36:18.780 --> 00:36:34.890
Maya Fishbach (she): called mind the gap, they did a calculation, where they sold for where this mascot is at different medalists cities and they found that the location of the mask APP was not very sensitive to the medalists at.

184
00:36:35.190 --> 00:36:38.430
Maya Fishbach (she): At all like it only buried by a few solar masses.

185
00:36:39.330 --> 00:36:40.470
Juliana Garcia-Mejia: Because the.

186
00:36:41.160 --> 00:36:54.720
Maya Fishbach (she): Basically, because the stellar wins did not really affect like the carbon oxygen core mouse, and that was really what.

187

00:36:55.800 --> 00:37:01.200
Maya Fishbach (she): stats like where this this mass gap is this that carbon oxygen core.

188
00:37:02.730 --> 00:37:04.620
Maya Fishbach (she): And so, but, but then.

189
00:37:05.670 --> 00:37:16.350
Maya Fishbach (she): Like they only evolved helium stars like assuming that during binary evolution and everything in the stars like before it would have lost the hydrogen.

190
00:37:16.740 --> 00:37:29.430
Maya Fishbach (she): envelope, and then, especially after dw 1905 21 that 85 solar mass black hole detection, there have been other papers that say like no you actually.

191
00:37:29.820 --> 00:37:43.590
Maya Fishbach (she): can hold on to the hydrogen envelope if you go to essentially zero medalist city so maybe like for population three stars, you can have the core.

192
00:37:44.550 --> 00:38:06.150
Maya Fishbach (she): be like below this mass gap range, but then you just have like 20 solar masses and hydrogen envelope that falls onto the platform that can push it up and so that would depend on medalists at um but yeah I don't think there is consensus on that yet sorry for the very long answer.

193
00:38:06.630 --> 00:38:08.910
Juliana Garcia-Mejia: Well, this is great Thank you so much.

194
00:38:11.310 --> 00:38:13.200
Floor Broekgaarden [she/her/hers]: Ryan, or do you want to follow up or.

195
00:38:15.750 --> 00:38:18.960
Rainer S Weinberger: I think I had more or less the same question, so I think that's.

196
00:38:21.270 --> 00:38:24.090
Rainer S Weinberger: about it, but I mean it generally just a.

197
00:38:25.980 --> 00:38:35.280

Rainer S Weinberger: What I would be interested in and i'm totally not in working in that field is, but do you have a clear sense of or.

198
00:38:36.570 --> 00:38:50.220
Rainer S Weinberger: Ideas how to how to solve problems like your your lifetime or in spiral time distribution and things like this, where this can be constrained in some crazy baby at some point in the future.

199
00:38:53.370 --> 00:38:54.930
Maya Fishbach (she): yeah so um.

200
00:38:55.200 --> 00:38:58.470
Maya Fishbach (she): I think we definitely so.

201
00:38:59.790 --> 00:39:00.390
Maya Fishbach (she): I had a.

202
00:39:01.980 --> 00:39:13.620
Maya Fishbach (she): I think like looking at the rate evolution, especially when we really start to be able to do that, like with in different mass spins.

203
00:39:14.070 --> 00:39:23.220
Maya Fishbach (she): I think that will really clear up the picture I mean here i'm just showing like in to mass spins well mass and high mass.

204
00:39:24.090 --> 00:39:45.120
Maya Fishbach (she): For for two different models which look kind of very different but eventually we'll have enough data, where this will be a solved problem right like we can just look at all of our 10 solar mass black holes and map out the rate the astrophysical rate of those as a function of redshift.

205
00:39:46.560 --> 00:39:49.590
Maya Fishbach (she): And then I think that will.

206
00:39:50.700 --> 00:39:56.730
Maya Fishbach (she): Like assuming that the time delay distribution doesn't depend too much on mass.

207
00:39:57.990 --> 00:40:13.950
Maya Fishbach (she): I think that's a good assumption from like population synthesis papers that i'm Fred but I don't know if that's up

for debate, but assuming that, then I think will really be able to go back to like Okay, then what is the.

208
00:40:14.730 --> 00:40:33.300
Maya Fishbach (she): Formation rate of the progenitors to the systems as a function of redshift and if it really is different for the 10 solar mass black holes like if the the 10 solar mass black holes their merger rate increases.

209
00:40:34.800 --> 00:40:44.670
Maya Fishbach (she): in a different way with redshift than like the 30 solar mass black holes, then I think we'll be able to say that the it really is.

210
00:40:45.720 --> 00:40:52.080
Maya Fishbach (she): dependent on the medalists at evolution and kind of disentangle that.

211
00:40:53.880 --> 00:41:06.840
Maya Fishbach (she): With yeah with the current generation of gravitational wave detectors we will really be able to probe much past redshift one like will probably get to like 1.5.

212
00:41:08.220 --> 00:41:23.430
Maya Fishbach (she): So we probably won't resolve the peak of the start the peak of the merger rate in like as a function of mass we can learn more about the high redshift universe by analyzing the stochastic background.

213
00:41:24.480 --> 00:41:29.970
Maya Fishbach (she): So I think there's like a limit to how much will be able to push this, but it will.

214
00:41:31.200 --> 00:41:34.380
Maya Fishbach (she): we're definitely not that limit yeah well i'm we're definitely gonna learn a lot more.

215
00:41:37.290 --> 00:41:39.180
Floor Broekgaarden [she/her/hers]: yeah I would actually follow up on that and.

216
00:41:39.810 --> 00:41:47.940
Floor Broekgaarden [she/her/hers]: I think you already hinted to that, but so now like a has 50 detections, as you mentioned, and so I imagine that the current redshift.

217
00:41:48.240 --> 00:41:59.520
Floor Broekgaarden [she/her/hers]: distribution is still dependent on like the prior to issue for how they're distributed so do you have any idea like what when how many detections do you need to kind of converge on this or.

218
00:42:02.730 --> 00:42:03.540
Maya Fishbach (she): yeah so.

219
00:42:03.600 --> 00:42:07.350
Maya Fishbach (she): um I think we're actually converging.

220
00:42:08.490 --> 00:42:15.060
Maya Fishbach (she): Really quickly on this, so I think now our number is like.

221
00:42:17.790 --> 00:42:25.830
Maya Fishbach (she): I mean what we do is we we measure the slope of this redshift evolution like it's one plus the two some slope.

222
00:42:26.940 --> 00:42:47.040
Maya Fishbach (she): And we've we've constrained that slope to be like plus or minus three now, which translates to the merger so that says, if we assume that the mass distribution does not evolve with redshift to the.

223
00:42:48.060 --> 00:42:59.670
Maya Fishbach (she): rate is the same at all masses we get that at redshift one, the rate is like no more than 10 times higher.

224
00:43:00.750 --> 00:43:03.900
Maya Fishbach (she): than the rate at a redshift zero.

225
00:43:05.250 --> 00:43:14.100
Maya Fishbach (she): And it also doesn't like it's it's pretty much does evolve with redshift but no more than like a factor of 10.

226
00:43:15.450 --> 00:43:25.800
Maya Fishbach (she): For with a second observing run that number was like a million so we've already our uncertainty has already gone down by.

227
00:43:26.490 --> 00:43:46.140

Maya Fishbach (she): orders of magnitude and that's really because, like with the second observing ground we were only sensitive out to like redshift 0.5 so we now just have a much longer lover arm to like constraints that rate evolution um and yeah, so I think.

228
00:43:47.400 --> 00:44:00.630
Maya Fishbach (she): I think now we're at the point where like that uncertainty is just going to decrease with the with the number of detections and depending on like where exactly it falls.

229
00:44:01.200 --> 00:44:11.340
Maya Fishbach (she): That can definitely tell you things about like the star formation rate and the the time delete distribution already like.

230
00:44:12.090 --> 00:44:26.760
Maya Fishbach (she): I guess for reference the like the model Dickinson star formation rate increases by a factor of six between zero and one and our like between zero and 10 so we're kind of in in that range, but if we.

231
00:44:29.400 --> 00:44:46.500
Maya Fishbach (she): yeah if we if we say like it must the rate increases with redshift much faster than like the meadow Dickinson star formation rate, I think that will be really interesting that definitely would say that, like medalists at evolution has something to do with it.

232
00:44:49.290 --> 00:44:49.680
Maya Fishbach (she): Thanks.

233
00:44:50.040 --> 00:44:51.450
Floor Broekgaarden [she/her/hers]: Morgan, do you want to follow up.

234
00:44:53.460 --> 00:44:55.410
Morgan Elowe MacLeod: Absolutely yeah so i'm.

235
00:44:56.340 --> 00:44:57.150
Morgan Elowe MacLeod: i'm really.

236
00:44:57.570 --> 00:45:06.330
Morgan Elowe MacLeod: interested in and also like still a little bit confused about it, but only because of my not being able to like dig through all the parts of it, I want so.

237
00:45:08.670 --> 00:45:09.300

Morgan Elowe MacLeod: In.

238
00:45:10.620 --> 00:45:21.900
Morgan Elowe MacLeod: Okay, so i'm sorry so thinking about the like non detection, a very large black holes at lower red shifts.

239
00:45:24.300 --> 00:45:25.710
Morgan Elowe MacLeod: So is the.

240
00:45:30.450 --> 00:45:34.020
Morgan Elowe MacLeod: As I understand the argument basically we if.

241
00:45:37.650 --> 00:45:50.580
Morgan Elowe MacLeod: If we fit one mass distribution to all redshift, then we would and the rate doesn't evolve with redshift, then we would expect to see them a low redshift Is that correct.

242
00:45:52.410 --> 00:45:53.850
Maya Fishbach (she): yeah and yeah.

243
00:45:54.390 --> 00:45:57.810
Morgan Elowe MacLeod: Does the volume become too small, essentially for the red SIP.

244
00:45:58.200 --> 00:45:59.580
Morgan Elowe MacLeod: That we're observing.

245
00:46:01.170 --> 00:46:02.910
Morgan Elowe MacLeod: Like in redshift point one.

246
00:46:04.620 --> 00:46:06.480
Maya Fishbach (she): yeah, this is a really.

247
00:46:07.950 --> 00:46:20.850
Maya Fishbach (she): Good question and I think we have some plots and in this paper to try to get this because you're like you're absolutely right, right now, our conclusion is that.

248
00:46:21.720 --> 00:46:36.540
Maya Fishbach (she): We don't yet have enough data to say whether the absence of black holes of the high mass black holes so up here at low redshift whether that is.

249
00:46:37.620 --> 00:46:50.850
Maya Fishbach (she): surprising, or whether the volume is just too small, and so there is some tension which is shown here between like in orange is our observations.

250
00:46:52.260 --> 00:47:01.530
Maya Fishbach (she): Basically, and in blue is what we would have predicted, there are a lot more than 50 points here because it's showing like different draws from.

251
00:47:01.890 --> 00:47:15.150
Maya Fishbach (she): This because we have uncertainty in our observations, but yeah so we so right now we can't distinguish between those, which is why we can't really say like is there really an absence like is.

252
00:47:16.440 --> 00:47:21.780
Maya Fishbach (she): Is in the universe is are there really just no big black holes that low redshift.

253
00:47:22.830 --> 00:47:33.510
Maya Fishbach (she): We can't say that yet, but we, we will be able to, so this is essentially taking that earlier Pol Pot and.

254
00:47:35.010 --> 00:47:51.300
Maya Fishbach (she): and showing like the fraction of high mass detections that low redshift compared to the fraction of high math detection that hi rich tips that we expect from like these two different possibilities.

255
00:47:52.410 --> 00:48:13.740
Maya Fishbach (she): And on this side, you can see that, right now, with only 44 events in this analysis, this is why we can't really distinguish that because the post on uncertainty is too big so it's not surprising that we have seen pretty much zero high loss events that little right shifts.

256
00:48:13.860 --> 00:48:23.430
Maya Fishbach (she): But the underlying productions from the two are very different so there's some prediction or just assuming.

257
00:48:24.570 --> 00:48:33.900
Maya Fishbach (she): If you if you assume that there's this known evolving broken power law there's just the low rate of high mass mergers at all redshift.

258
00:48:35.250 --> 00:48:48.030
Maya Fishbach (she): Then you definitely predict to detect like one of these high mass events at low redshift for every three timeouts events at high redshift.

259
00:48:49.110 --> 00:48:50.520
Maya Fishbach (she): And so, when we have like.

260
00:48:51.390 --> 00:48:54.600
Maya Fishbach (she): 10 high mass events and high redshift.

261
00:48:55.620 --> 00:49:09.000
Maya Fishbach (she): That it's like we would expect like three of those that low right chef not becomes more significant when we have 20 high red chefs, then you, like you, basically when with the questions.

262
00:49:11.280 --> 00:49:17.670
Morgan Elowe MacLeod: Will as we talk about like this generation of gravitational wave detectors and going from the.

263
00:49:18.780 --> 00:49:22.020
Morgan Elowe MacLeod: Zero to 1.5 does.

264
00:49:23.190 --> 00:49:34.410
Morgan Elowe MacLeod: is essentially the time baseline constraining below lowest redshift and, like the small volume and is that going to be as much of a challenge as sort of pushing down into the noise on hiring.

265
00:49:36.810 --> 00:49:39.000
Maya Fishbach (she): And yeah so with the low.

266
00:49:40.140 --> 00:49:52.830
Maya Fishbach (she): window redshift and it's mostly just time and I mean I was we we do improve our sensitivity, but you know out to like redshift point one.

267
00:49:53.610 --> 00:50:01.440
Maya Fishbach (she): or so like very low redshift where we can say like we're observing all of the black holes that merge.

268
00:50:02.010 --> 00:50:15.120

Maya Fishbach (she): So that limit is set by how many refrigerators are there, and the reason we're detecting so many more events overall is because our sensitivity is increasing at the highest redshift so we're able to.

269
00:50:15.570 --> 00:50:32.580
Maya Fishbach (she): pick out more of those mergers out of the noise but yeah with like the plan to third generation gravitational wave detectors like the ideas that will be observing every single binary black hole merger in the universe, so the.

270
00:50:33.840 --> 00:50:51.570
Maya Fishbach (she): I was gonna say the only limit is how many of these mergers, there are, but really there's also the limit of like how good our computer is in her computational techniques are to analyze like hundreds of thousands of events annually.

271
00:50:54.450 --> 00:51:13.080
Floor Broekgaarden [she/her/hers]: Thanks yeah that's incredible um another question that was put up was actually What about the richest dependent the orbit of evolution of like mass ratio or the mass ratio by your black holes or otherwise um other sources such as binary your concerns.

272
00:51:14.850 --> 00:51:15.330
Maya Fishbach (she): yeah.

273
00:51:15.840 --> 00:51:16.470
Maya Fishbach (she): yeah that is.

274
00:51:16.920 --> 00:51:39.780
Maya Fishbach (she): A great question, so this is really like we've only taken the first two steps so far, which is looking at how the overall murder rate evolved with redshift and then looking at how like the primary mass distribution evolves with redshift we've also looked at how.

275
00:51:40.890 --> 00:51:51.720
Maya Fishbach (she): Like whether there's some like mass ratio dependence with redshift and the uncertainties were just really broad but there's definitely.

276
00:51:53.610 --> 00:51:59.370
Maya Fishbach (she): yeah I mean really like we would want to look at all of the properties and.

277

00:52:00.390 --> 00:52:12.750
Maya Fishbach (she): we're we're kind of in the stage now where our simplest like parametric models are no longer a good description of the data like we.

278
00:52:13.710 --> 00:52:24.630
Maya Fishbach (she): We used to just fit for one power loss slope, and like clearly now that doesn't work like if we do that, then we have to also say that the that value.

279
00:52:25.140 --> 00:52:37.350
Maya Fishbach (she): is different at different redshift some so we're adding like just another parameter and we're still just add in like a handful printed really good out another parameter to describe Okay, how does the mass ratio distribution.

280
00:52:37.890 --> 00:52:46.170
Maya Fishbach (she): involved with redshift but then we realize like Oh, we can't really learn everything anything about that so let's like take that perimeter away um.

281
00:52:46.860 --> 00:52:59.820
Maya Fishbach (she): But yeah like eventually, this is just moving towards will have thousands of these, and we can do a fully like we'll just have the underlying distribution.

282
00:53:00.330 --> 00:53:19.110
Maya Fishbach (she): In some non parametric way, we can see, like our which properties are changing with redshift which properties are constant in redshift are they co evolving and some way that points at a specific formation channel as the likely one.

283
00:53:20.220 --> 00:53:25.320
Maya Fishbach (she): So yeah that's that's definitely going to get more interesting when we have more data.

284
00:53:29.370 --> 00:53:29.670
Floor Broekgaarden [she/her/hers]: Great.

285
00:53:29.700 --> 00:53:45.390
Floor Broekgaarden [she/her/hers]: Thanks so much i'm also seeing that we're four minutes before noon so and I don't want to hold it, I want to give people some time before our next meeting so unless there's any urgent questions i'm going to thank my again for her top.

286

00:53:46.320 --> 00:53:48.570
Floor Broekgaarden [she/her/hers]: So i'm going to give her pause.

287
00:53:50.310 --> 00:53:53.010
Floor Broekgaarden [she/her/hers]: um yeah and Morgan this or anything.

288
00:53:53.040 --> 00:53:54.390
Morgan Elowe MacLeod: I had any like.

289
00:53:54.480 --> 00:54:03.780
Morgan Elowe MacLeod: last words on like what are you most excited about working on next like what are your vision for next steps that you're particularly excited about.

290
00:54:06.930 --> 00:54:21.930
Maya Fishbach (she): yeah so um I think I definitely think that, like some of the questions about Okay, what is this actually telling us about the star formation rate or like the medalist at the evolution of the universe.

291
00:54:22.860 --> 00:54:37.200
Maya Fishbach (she): I think those are those are really interesting and I i'm really like I think thinking more about that i'm really excited about that i'm also really excited to like actually learn more about.

292
00:54:37.770 --> 00:54:47.400
Maya Fishbach (she): Like other probes of those of those things, and like basically tie this gravitational wave data to to other observations of.

293
00:54:47.430 --> 00:54:49.020
Maya Fishbach (she): The universe so.

294
00:54:49.860 --> 00:54:50.700
Maya Fishbach (she): yeah I would.

295
00:54:51.060 --> 00:55:03.330
Maya Fishbach (she): If anyone anyone wants to collaborate on on things like that I would love to step out of like the lygo data analysis world for for like a paper to.

296
00:55:06.240 --> 00:55:14.940
Morgan Elowe MacLeod: amazing well Thank you so much, and thank you to everyone for the great discussion, and thank you especially to Florida for guiding us through.

297
00:55:16.830 --> 00:55:18.600
Morgan Elowe MacLeod: yeah Thank you everyone and we'll see you soon.

298
00:55:20.040 --> 00:55:20.580
Maya Fishbach (she): Thank you.