WEBVTT

1
00:00:04.170 --> 00:00:08.220
Sarah Jeffreson: And then, for people who would find it useful, the.

2
00:00:08.250 --> 00:00:10.380
Sarah Jeffreson: Closed captioning is also.

3
00:00:10.469 --> 00:00:16.139
Tamara Bogdanovic: Just click click on the guided part, so that I can see my slides.

4
00:00:17.160 --> 00:00:17.940
Tamara Bogdanovic: restarted again.

5
00:00:20.040 --> 00:00:20.910
Sarah Jeffreson: Thank you so much.

6
00:00:22.470 --> 00:00:30.660
Tamara Bogdanovic: Well, thank you very much for for a very nice introduction, thank you for inviting me to present this colloquium.

7
00:00:31.980 --> 00:00:43.020
Tamara Bogdanovic: I will discuss today, the results of our relatively recent study and i'll talk about the properties of dual action galactic nuclei that become.

8
00:00:43.830 --> 00:00:51.690
Tamara Bogdanovic: Eventually gravitational waves services and host mergers for binary supermassive black horse.

9
00:00:52.650 --> 00:01:10.140
Tamara Bogdanovic: So I will first introduce my collaborators, so the work that I will discuss today was mostly done by Kenyan Lee a graduate student in Georgia tech for her PhD thesis and in collaboration with David Valentine and not to burn it.

10
00:01:11.790 --> 00:01:21.900
Tamara Bogdanovic: Please interrupt me if you cannot hear well and feel free to ask any questions during the presentation that's totally okay or save them for later that's also good too.

11
00:01:23.520 --> 00:01:36.540

Tamara Bogdanovic: So a duo he is those that killer our second largest separations are actually our most definitive observational evidence that massive black hole pairs exists and.

12
00:01:36.990 --> 00:01:44.460
Tamara Bogdanovic: More even more interestingly, these are the progenitors of massive level murders and gravitational wave sources associated with them.

13
00:01:46.140 --> 00:01:53.160
Tamara Bogdanovic: You can see some number of examples here in this gallery from the masculine at all.

14
00:01:54.090 --> 00:02:15.720
Tamara Bogdanovic: And all see that moving towards detection of massive Bible peers at smaller scale smaller than calabar sick and certainly smaller than parcel has been very challenging largely because of a small anger or separation of this peers in the sky, which makes it difficult to distinguish to.

15
00:02:17.190 --> 00:02:27.270
Tamara Bogdanovic: Massive black holes, even if they are creating from a single massive black hole in a single agent and so these are, this is our best evidence.

16
00:02:27.720 --> 00:02:39.240
Tamara Bogdanovic: That massive Bible Paris forum in the universe, and the work that i'm going to discuss is actually motivated by some of these questions so some of these.

17
00:02:40.020 --> 00:02:51.300
Tamara Bogdanovic: Massive by called peers will eventually and in mergers, but can we tell which ones are more likely to merge and others how long does it take.

18
00:02:51.810 --> 00:03:04.620
Tamara Bogdanovic: For them to merge and which dynamical processes, Dr orbital evolution and which are the most important for massive black hole appears as a population, not necessarily an individual case by case basis.

19
00:03:06.120 --> 00:03:16.110
Tamara Bogdanovic: Also, can be incidence of new agey hands on the sky can be used to predict the coalescence rate of massive black holes and.

20

00:03:17.190 --> 00:03:28.080
Tamara Bogdanovic: inverting that question if eventually measured the coalescence cosmological coalescence rates of massive by calls from St gravitational wave observations are we going to be able to.

21
00:03:29.100 --> 00:03:33.030
Tamara Bogdanovic: learn something important about your agents on the sky.

22
00:03:39.300 --> 00:03:40.860
Mila Chadayammuri: hate America quick question.

23
00:03:41.490 --> 00:03:50.460
Mila Chadayammuri: Yes, so when you talk about massive black holes there's just a terminology that I think people use differently so, can you please define like.

24
00:03:51.270 --> 00:03:59.700
Mila Chadayammuri: Superman are you talking about supermassive black holes, are you talking about like an intermediate math regime like things that maybe live in dwarf galaxies or like what is massive.

25
00:04:00.210 --> 00:04:09.990
Tamara Bogdanovic: Excellent question Okay, so let me just fast forward to the next slide So when I say massive black holes I.

26
00:04:10.650 --> 00:04:23.130
Tamara Bogdanovic: Generally mean 10 to the five to 10 to the 10 but for the purposes of this talk, I will be focusing on massive black holes with mass larger than million solar masses, let me explain why.

27
00:04:23.820 --> 00:04:36.270
Tamara Bogdanovic: So i'll just introduce some most important aspects of our calculation, so that you understand what's behind it basically we start by drawing massive black holes bears from the D amp D.

28
00:04:37.320 --> 00:04:53.610
Tamara Bogdanovic: simulation and tinge of 50 is a part of a larger illustrious di n G suite of cosmological simulations it has physical volume of approximately 50 coming mega piracy cube so the important aspect that you just asked about.

29
00:04:54.780 --> 00:05:04.290

Tamara Bogdanovic: Is that in this simulations black holes when their master black holes when they're born they're born with a minimum so about 10 to the six or masses.

30
00:05:05.430 --> 00:05:13.440
Tamara Bogdanovic: So, in other words are basically the model assumes heavy massive but mckenney black or seed formation.

31
00:05:15.270 --> 00:05:23.340
Tamara Bogdanovic: And this will be important later on when we visit to make predictions for coalescence rates and so on, there are about 2200.

32
00:05:24.660 --> 00:05:44.910
Tamara Bogdanovic: mph peers within the simulation volume and they reach minimum separation of about one or two kilo parsecs which is set why the gravitational softening of the collision less component or conditions particles in in the simulation.

33
00:05:46.440 --> 00:06:01.230
Tamara Bogdanovic: Like dark matter and stars and those black hole pairs massive Michael pairs are drawn from simulation and similar way that they've been drawn for some earlier works that basically focused on the illustrates a sister simulation from this sweet.

34
00:06:03.660 --> 00:06:06.360
Tamara Bogdanovic: As was done by Laura black hand Luke Kelly.

35
00:06:07.980 --> 00:06:24.720
Tamara Bogdanovic: We created the semi analytic model to evolve massive black hole peers to smaller separations you to the effects of stellar and gases dynamical friction in the merger random galaxy you to the stellar last count scattering.

36
00:06:25.950 --> 00:06:39.900
Tamara Bogdanovic: You to the the interactions with a certain binary disk and due to the emission rotational waves, but we do not take into account interactions.

37
00:06:40.920 --> 00:06:56.010
Tamara Bogdanovic: With triple or higher order interactions with either massive black holes that may happen when the evolution of the pair is very long and there is another merger, that means yet another massive like all on board.

38
00:06:57.060 --> 00:06:57.930

Tamara Bogdanovic: So those are neglect.

39
00:06:59.460 --> 00:07:15.870
Tamara Bogdanovic: Okay ah this inset is basically showing the redshift distribution or massive wacko peers when they're drawn from the simulation and you can see that it's relatively broad distribution that extends to redshift about five.

40
00:07:16.920 --> 00:07:35.010
Tamara Bogdanovic: will come back to this distribution later, so our semi analytic model involves the Pier in a merger redmond galaxy we assume that there is a single galaxy at that point when they're at separation about one person with a single star Raj and a single gas desk.

41
00:07:36.150 --> 00:07:46.500
Tamara Bogdanovic: We do non models, the effect of the stellar desk stellar ago your lighting desk because we find that it doesn't make a huge difference for.

42
00:07:46.920 --> 00:08:02.610
Tamara Bogdanovic: The evolution of massive iPod peers as a population and consider to black holes known spinning with the more mass one placed at the Center of the remnant galaxy and the lower mass black hole place somewhere in the desk.

43
00:08:04.020 --> 00:08:05.160
Tamara Bogdanovic: Of the remnant galaxy.

44
00:08:06.570 --> 00:08:16.140
Tamara Bogdanovic: So all our merger Ram and galaxies are described by seven parameters by the black hole pair mass and their mass ratio.

45
00:08:17.220 --> 00:08:27.690
Tamara Bogdanovic: by the mass and size of the stellar voltage and mass in size of the gas desk as well as the rotational velocity of the gas desk.

46
00:08:29.640 --> 00:08:39.420
Tamara Bogdanovic: All these parameters are informed by all been the last one are informed by the values from the.

47
00:08:40.440 --> 00:08:52.620
Tamara Bogdanovic: cosmological simulation and for the last one we just make an assumption that rotational velocity of the gas desk is somewhere between 70 and 90% of the circular velocity.

48
00:08:54.510 --> 00:08:58.830
Tamara Bogdanovic: Of the galaxy and then even radius So these are just the most important ingredients.

49
00:08:59.880 --> 00:09:08.160
Tamara Bogdanovic: There is more detail in this group of publications that i'm showing here in case that you're interested in, and of course you can always ask me.

50
00:09:10.200 --> 00:09:11.370
Tamara Bogdanovic: If you have any questions.

51
00:09:12.510 --> 00:09:25.560
Tamara Bogdanovic: So let's first start with a with a timescales for evolution of massive level parents as we calculate them from from this model so basically from kill parsecs one or two kilo parsecs separations down to merger.

52
00:09:26.730 --> 00:09:30.570
Tamara Bogdanovic: So on the left hand side let's just first focus on on that.

53
00:09:31.890 --> 00:09:41.340
Tamara Bogdanovic: histogram, this is a histogram of times that black hole pair spent in the phase that is.

54
00:09:42.390 --> 00:09:45.120
Tamara Bogdanovic: dominated by dynamical friction.

55
00:09:46.170 --> 00:10:05.460
Tamara Bogdanovic: Generally, from one killer parsing down to about one or 10% separations and they're about 8700 peers in this histogram which corresponds to the original number of years 2165 drawn from the tmj 50 times for different.

56
00:10:06.750 --> 00:10:21.210
Tamara Bogdanovic: types of orbits the that we consider in our model that includes program and retrograde orbits and consider it a low or high eccentricity orbits and, in this case the ground because he.

57
00:10:22.440 --> 00:10:22.740
Sarah Jeffreson: got a.

58
00:10:24.870 --> 00:10:31.680
Sarah Jeffreson: retrograde here referred to proceed with the rotation of the disk and the orbit of the black hole or what's the.

59
00:10:32.670 --> 00:10:44.970
Tamara Bogdanovic: Yes, good question, so the program means relative to the desk or in the rotating in the same sense as the galactic this gas this or retrograde in in the opposite sounds from the.

60
00:10:45.300 --> 00:10:46.050
Sarah Jeffreson: rv all.

61
00:10:47.880 --> 00:10:51.150
Sarah Jeffreson: Or is it more was the physical distribution.

62
00:10:52.740 --> 00:10:58.920
Tamara Bogdanovic: The secondary lower amounts black hole is in our model always placed in the point.

63
00:11:00.060 --> 00:11:02.550
Tamara Bogdanovic: It always placed into play no data yeah.

64
00:11:05.040 --> 00:11:16.740
Sarah Jeffreson: I have another question when you were describing how you set up your model and previous slide and do you just use a snapshot of one of these properties in the forums, or do you allow us to evolve over time.

65
00:11:18.660 --> 00:11:38.820
Tamara Bogdanovic: We just use a snapshot basically that is defined by the last snapshot in which the pair of massive black holes in the tg 50 simulation reaches the mineral separation so from that snapshot we draw information about the the galaxy.

66
00:11:39.990 --> 00:11:49.950
Tamara Bogdanovic: Around the more massive black hole about the stellar content and gas, content and that's what we use to describe their own gods we don't evolve this properties, with time.

67
00:11:52.740 --> 00:11:53.820
Sarah Jeffreson: And what does it mean to be.

68
00:11:53.820 --> 00:11:58.740

Sarah Jeffreson: stalled, but at perfection time scale tend to the years.

69
00:12:00.420 --> 00:12:16.920
Tamara Bogdanovic: Okay, so that's a good question, you can see in this panel that basically timescales for evolution or along, but for some there, there are two groups here they're marked with hatched bars that dawn.

70
00:12:17.940 --> 00:12:24.000
Tamara Bogdanovic: call us within the hubble time or by redshift of zero actually and.

71
00:12:25.590 --> 00:12:40.050
Tamara Bogdanovic: Poor those that stole that group around the time of tend to they tend to the nine years they actually stole it smaller separations so they don't store necessarily while they're in the dynamical friction stage.

72
00:12:41.580 --> 00:12:55.950
Tamara Bogdanovic: But they stall when they move to separations where stellar loss comes kettering dominates so they're dynamical friction time is kind of reasonable some the order of tend to they tend to the nine years but later on, basically, they.

73
00:12:57.030 --> 00:12:57.690
Tamara Bogdanovic: they stole.

74
00:12:58.470 --> 00:13:00.210
Sarah Jeffreson: Well that's very interesting okay.

75
00:13:01.920 --> 00:13:09.300
Tamara Bogdanovic: Right yeah there are there are some very diffuse extended galaxies that would basically need to that kind of evolution.

76
00:13:09.630 --> 00:13:21.480
Tamara Bogdanovic: For the address they basically exceed a couple time already in the dynamic of friction stage and that's the the last group of bars, that is false around 10 to the 10.

77
00:13:22.950 --> 00:13:23.460
Tamara Bogdanovic: years.

78
00:13:24.780 --> 00:13:25.140
Tamara Bogdanovic: Okay.

79
00:13:27.120 --> 00:13:28.890
Tamara Bogdanovic: Any other questions.

80
00:13:31.650 --> 00:13:51.150
Tamara Bogdanovic: If not let's move to the next panel so for for those a black hole peers that basically have all successfully through the dynamical friction stage they become gravitational inbound and they become subject to other dynamical effects of the lead to the orbital evolution of.

81
00:13:52.230 --> 00:13:54.330
Tamara Bogdanovic: Those stages for gravitationally bound.

82
00:13:55.680 --> 00:14:04.530
Tamara Bogdanovic: black hole peers stellar loss clones kettering tends to dominate or interactions with the circle binary this and eventually.

83
00:14:06.150 --> 00:14:12.330
Tamara Bogdanovic: emission of gravitational waves are the smallest separation, so this middle panel is showing the time scale for those.

84
00:14:13.830 --> 00:14:35.820
Tamara Bogdanovic: Those three mechanisms, and you can see that Okay, the time scales are bit shorter and shorter than for the dynamic compression stage are they they are about 10 to the 710 to the eight and there is actually a broad range so anymore these up together.

85
00:14:37.230 --> 00:14:53.580
Tamara Bogdanovic: gives us the total time to merger from one or two kids are sick separation down to call essence and what I wanted to basically highlight here is that this last histogram looks very similar to the first one.

86
00:14:55.110 --> 00:15:01.110
Tamara Bogdanovic: minus the the bars for the stalled pairs you can see that they might Michael friction.

87
00:15:02.880 --> 00:15:15.810
Tamara Bogdanovic: Is the dynamic of friction stage is the defining one effectively that determines what or a majority of the sample will call us or not and that's interesting because.

88
00:15:16.290 --> 00:15:26.370

Tamara Bogdanovic: From theoretical point of view, a you know that this is the bottleneck, but be if you take a set of dual agents that.

89
00:15:27.000 --> 00:15:36.450
Tamara Bogdanovic: You know, are likely to merge, you only need to model them through the dynamical friction phase, and you can obtain a reasonable estimate for the coalescence rate.

90
00:15:36.960 --> 00:15:47.610
Tamara Bogdanovic: Of master black holes, you can neglect evolution at smaller scales all the individual you don't know which exact each pair exactly we're merging which one will not, but you will get a good.

91
00:15:48.690 --> 00:15:49.230
Tamara Bogdanovic: guess.

92
00:15:50.850 --> 00:15:57.510
Sarah Jeffreson: What is the denominator here this looks like a total number of the parent and $1 60 parents.

93
00:15:57.510 --> 00:15:58.560
Sarah Jeffreson: What was the volume of.

94
00:15:58.590 --> 00:15:59.370
The simulation.

95
00:16:00.510 --> 00:16:09.600
Tamara Bogdanovic: The volume of the simulation is that of the tg 50, which is about 50 kilo parsecs following counterparts excuse.

96
00:16:12.240 --> 00:16:14.190
Sarah Jeffreson: What does that turn into in terms of.

97
00:16:14.190 --> 00:16:14.820
race.

98
00:16:16.170 --> 00:16:16.590
Sarah Jeffreson: or.

99
00:16:18.540 --> 00:16:19.140
up.

100

00:16:21.060 --> 00:16:22.170
Sarah Jeffreson: People are sick let's say.

101
00:16:25.260 --> 00:16:26.670
Tamara Bogdanovic: I don't know let's be divided.

102
00:16:28.200 --> 00:16:31.080
Tamara Bogdanovic: By by the volume at the end of the presentation, but.

103
00:16:32.130 --> 00:16:39.240
Tamara Bogdanovic: Presumably it's basically the density you're probably asking about the the density of.

104
00:16:40.800 --> 00:16:44.820
Tamara Bogdanovic: cosmological density or massive why calls per unit mega persecuted or something like that.

105
00:16:46.110 --> 00:16:49.860
Tamara Bogdanovic: We can calculate it but it's basically whatever is given by the.

106
00:16:52.290 --> 00:17:01.560
Tamara Bogdanovic: simulation Plus we we model this for different configurations here so for us is a just a sample, then the number is not important just yet.

107
00:17:03.960 --> 00:17:04.950
Yes.

108
00:17:07.080 --> 00:17:09.480
Tamara Bogdanovic: We see that there is a is there a hand up.

109
00:17:12.150 --> 00:17:12.510
Sarah Jeffreson: earlier.

110
00:17:13.800 --> 00:17:14.550
Tamara Bogdanovic: Okay okay.

111
00:17:16.080 --> 00:17:17.940
Tamara Bogdanovic: So I will move on.

112
00:17:19.110 --> 00:17:24.930

Tamara Bogdanovic: And was there any other questions at this point, so there is also second interesting.

113
00:17:26.070 --> 00:17:43.020
Tamara Bogdanovic: implication of the fact that the total time is determined by the dynamical friction stage, and that is that if you measure, a call us rates rate or massive black holes from gravitational waves, you will be directly constraining the efficiency of dynamical friction.

114
00:17:44.190 --> 00:17:45.720
Tamara Bogdanovic: Effectively, your are.

115
00:17:47.490 --> 00:17:56.970
Tamara Bogdanovic: So we'll keep that in mind, and what we'll move on to basically look at the ratio distribution of massive life or peers that that merge.

116
00:17:58.440 --> 00:18:07.410
Tamara Bogdanovic: From the sample so I showed you already the panel on the left, this is the initial distribution of massive black hole pairs or as they're gone from the.

117
00:18:08.100 --> 00:18:24.180
Tamara Bogdanovic: simulation so it's a relatively broad distribution when we evolved them through all the dynamical processes that I mentioned, and when required, only the call, I see the group that coalesces the distribution that merger is shown on the right.

118
00:18:25.320 --> 00:18:42.930
Tamara Bogdanovic: And you can see that at the time when they merge most mergers or curate relatively low redshift mostly below the redshift have to which is good news for the electromagnetic follow up potential outcome magnetic follow up all.

119
00:18:44.190 --> 00:18:52.350
Tamara Bogdanovic: Of these sources, you can see that, because we distinguish between the pro rate and retrograde orbits programmed orbits are a bit more.

120
00:18:52.830 --> 00:19:06.660
Tamara Bogdanovic: favored in the sounds that they they will lead to higher not fractional call essences then retrograde orbits, and this has mostly to do with the basically dynamical friction.

121

00:19:08.580 --> 00:19:21.270
Tamara Bogdanovic: which depends on the MAC number in relative motion or per server to the gas, so it matters, whether it orbits in progress or or retrograde direction relative to the galactic as disk.

122
00:19:22.290 --> 00:19:28.860
Tamara Bogdanovic: So we know that 71% of progress pairs merge, as opposed to 39% of retrograde there.

123
00:19:31.680 --> 00:19:33.510
Tamara Bogdanovic: OK okay so.

124
00:19:34.680 --> 00:19:49.530
Tamara Bogdanovic: that's that distribution let's look at the properties of those systems that actually lead to massive work on mergers, because this is what we're hoping to understand the first panel on the left, shows the coalescence fraction.

125
00:19:50.910 --> 00:20:02.580
Tamara Bogdanovic: Is the function of the gas fraction of the merger ramlan galaxy and the gas fraction is defined, just as the mass of the gas total gas content of the galaxy.

126
00:20:02.760 --> 00:20:03.780
Sarah Jeffreson: divided by.

127
00:20:04.290 --> 00:20:06.810
Tamara Bogdanovic: The mass of the gas, plus the most of the stores don't.

128
00:20:08.340 --> 00:20:19.710
Tamara Bogdanovic: And you can see that, for both either prorate a retrograde orbits the coalescence fraction is actually highest when the gas fraction is pine.

129
00:20:21.390 --> 00:20:42.690
Tamara Bogdanovic: And this is telling us that, since we know that dynamical friction is the defining mechanism that determines basically the fate of most of the most of the pears pears and remodel this is donors, that the gas dynamical friction that matters right because the gas fraction.

130
00:20:43.980 --> 00:20:49.470
Tamara Bogdanovic: On determines or call us interaction, looking at the second panel.

131
00:20:50.910 --> 00:20:57.690
Tamara Bogdanovic: it's again courses fraction, but in this case versus the primary black hole mouse.

132
00:20:58.950 --> 00:21:06.540
Tamara Bogdanovic: And you can see that actually the call us instruction peaks at about 60 to 80% at the lower.

133
00:21:08.250 --> 00:21:10.920
Tamara Bogdanovic: Masses for for the primary black hole.

134
00:21:12.090 --> 00:21:24.090
Tamara Bogdanovic: And the reason why is that in the future 50 simulations lower thousand galaxies the coast lower mass black holes tend to be more gas rich.

135
00:21:25.620 --> 00:21:27.840
Tamara Bogdanovic: So we're basically looking at.

136
00:21:29.340 --> 00:21:30.390
Tamara Bogdanovic: Again, the.

137
00:21:32.040 --> 00:21:43.470
Tamara Bogdanovic: The other side of the same coin here which tells us that the US is dynamical friction plays an important role in the evolution of these pairs and drives them efficiently together.

138
00:21:46.140 --> 00:22:02.880
Tamara Bogdanovic: Looking at the the third panel This shows the costumes fraction versus the mass ratio of the black hole pair massive black hole care and not surprisingly, you, you see that for inappropriate or retrograde orbits.

139
00:22:04.350 --> 00:22:10.290
Tamara Bogdanovic: The call essences happen at a higher straight for comparable mass binaries.

140
00:22:11.460 --> 00:22:30.090
Tamara Bogdanovic: The reason is that the article friction again operate more efficiently on more massive protests servers so if the if both black holes are over comparable mass then uncle friction will be more efficient than the secondary then if the masses were desperate desperate and.

141
00:22:31.260 --> 00:22:45.390
Tamara Bogdanovic: The secondary was very low mass compared to the primary and again, you know what cases, we see that progress master black appears in progress orbits or leads more more coalescence.

142
00:22:48.660 --> 00:22:53.190
Tamara Bogdanovic: Okay, so that is all fine and well.

143
00:22:54.330 --> 00:22:56.070
Tamara Bogdanovic: let's actually now look at.

144
00:22:58.080 --> 00:23:06.570
Tamara Bogdanovic: The murder rates, the distribution of the murder rates as a function of the properties of.

145
00:23:07.680 --> 00:23:21.540
Tamara Bogdanovic: Demand merging systems and let's also see the implications for say Lisa detection rates Lisa the future space bass gravitational wave Observatory so let's start with the with the leftmost Pal i'm just showing.

146
00:23:23.250 --> 00:23:29.280
Tamara Bogdanovic: This differential murder rates for progress and low eccentricity systems.

147
00:23:30.540 --> 00:23:45.930
Tamara Bogdanovic: For all other configurations hikes and Christie retrograde and so on, we basically find similar distributions but different normalization, so there are qualitatively similar so let's just look at this case from the Left, this is basically a differential.

148
00:23:47.130 --> 00:24:02.550
Tamara Bogdanovic: murder rate in terms of the number of classes per unit logarithmic being of binary mass units redshift units time but integrated over a period of four years.

149
00:24:03.270 --> 00:24:25.440
Tamara Bogdanovic: which we pick as a nominal lifetime or the Lisa mission 10 so number differential number over four years and the color here shows that differential coalescence rate and you can see that basically a hot pixel appears somewhere around the redshift a 1.6.

150
00:24:26.550 --> 00:24:36.630

Tamara Bogdanovic: Well, maybe one ratchet one to two roughly just by eyeballing it and it costs us rate cosmological classes rate also peaks for.

151
00:24:37.170 --> 00:24:59.670
Tamara Bogdanovic: at lower la black hole PR masses somewhere between 10 and six and 10 to the songs or masses and that again is the consequence so his glasses being gas rich and gets his dynamical friction helping new systems to call essence relatively efficient the ones broken lines that you see.

152
00:25:00.090 --> 00:25:02.040
Tamara Bogdanovic: are actually representing.

153
00:25:02.490 --> 00:25:10.440
Tamara Bogdanovic: The signal to noise ratio of liza detections for those systems that have all to call essence.

154
00:25:11.550 --> 00:25:30.120
Tamara Bogdanovic: And you can see, not surprisingly, that the highest signal to noise ratio corresponds to the lower mass lower my systems and lower ratchets and signal to noise ratio eight is basically some nominal threshold that.

155
00:25:32.130 --> 00:25:43.890
Tamara Bogdanovic: implies a loser detection so higher signal to noise ratio events or considered detected by me so in those with their lower than eight are not going to be the attack.

156
00:25:44.610 --> 00:25:44.760
On.

157
00:25:46.800 --> 00:25:47.910
Tamara Bogdanovic: let's go ahead.

158
00:25:48.660 --> 00:25:52.560
Sarah Jeffreson: yeah what's the typical redshift there which these cycles are seated in this image.

159
00:25:54.810 --> 00:25:55.620
Tamara Bogdanovic: well.

160
00:25:58.590 --> 00:26:02.820

Tamara Bogdanovic: i'm not sure what is the typical redshift where they are seated.

161
00:26:04.470 --> 00:26:16.920
Tamara Bogdanovic: Basically I have distribution when they reach their minimal separations, but they are seated when galaxies and host elbows reached some.

162
00:26:17.700 --> 00:26:22.620
Tamara Bogdanovic: Threshold mass but I don't know what a typical ratchet is I would have to look that up.

163
00:26:23.310 --> 00:26:23.670
Okay.

164
00:26:24.960 --> 00:26:28.950
Sarah Jeffreson: yeah I had the impression that tactic or reprinting effective.

165
00:26:31.320 --> 00:26:35.910
Tamara Bogdanovic: um I I imagine that that's the case yes and.

166
00:26:37.260 --> 00:26:38.430
Tamara Bogdanovic: I imagine that.

167
00:26:39.810 --> 00:26:51.720
Tamara Bogdanovic: Many will be see that out to all the way out to redshift Dan maybe but probably not as much hi Richard and that just because the galactic heroes need to grow.

168
00:26:52.230 --> 00:26:53.940
Tamara Bogdanovic: And that's enough in order.

169
00:26:54.120 --> 00:26:59.010
Tamara Bogdanovic: to plant a 10 to the six or mass black or seed right in.

170
00:27:02.370 --> 00:27:02.820
Tamara Bogdanovic: Okay.

171
00:27:04.740 --> 00:27:18.510

Tamara Bogdanovic: Alright, so you can see that here nicely the the hotspot for the coalescence rate overlaps with Lisa contours so most of these events will be detected by Lisa that's basically the bottom line.

172
00:27:20.490 --> 00:27:28.440
Tamara Bogdanovic: Looking at the other two panels are it's basically the differential murder rate shown in the middle panel in terms of the.

173
00:27:29.580 --> 00:27:37.140
Tamara Bogdanovic: binary mass and the mass ratio so again, you see that lower binary masses are preferred and equal mass.

174
00:27:38.130 --> 00:27:52.350
Tamara Bogdanovic: ratios or comparable mass ratios, and these again set squarely within our Lisa signal to noise ratio contours about hundred so most should be detected and on the right hand side you basically see this.

175
00:27:55.710 --> 00:28:06.180
Tamara Bogdanovic: The differential coalescence rate in terms of the mass of the stellar bulge of the merger and then galaxy versus the gas stretch the.

176
00:28:07.230 --> 00:28:22.200
Tamara Bogdanovic: remnant galaxy and you see, you can see that most of the coalescence is happen at higher gas fractions higher than about 0.5 but yeah they're kind of distributed widely.

177
00:28:23.640 --> 00:28:35.910
Tamara Bogdanovic: Particular one, but you can see, this anti correlation effectively that so more massive biologists have low gas fraction and because of that somewhat lower coalescence rate than.

178
00:28:38.370 --> 00:28:41.370
Tamara Bogdanovic: than low mass bulges.

179
00:28:43.800 --> 00:28:59.790
Tamara Bogdanovic: Much but but Okay, so what is that we actually calculate for the actual cosmological murder rates what we find is a rate of about a half of call essence per year.

180
00:29:00.870 --> 00:29:14.100
Tamara Bogdanovic: And then, when we calculate Lisa detection rates, we find that it's similar but slightly lower value which kind of makes sense

because I just saw your based on this that most most common sense should be detected by nisa in this.

181
00:29:15.780 --> 00:29:18.870
Tamara Bogdanovic: setup so it's about 0.3 0.4.

182
00:29:20.430 --> 00:29:28.950
Tamara Bogdanovic: These rates voted the cosmological murder rate and Elisa predictions for the laser detection rates are actually comparable to.

183
00:29:29.640 --> 00:29:48.630
Tamara Bogdanovic: Those rates they're already in the literature and published but we're drawn from different cosmological simulations I showed us a couple examples here they include the the eagle simulation the last stress simulation or a sister simulation from the same suite has dmg 50.

184
00:29:50.280 --> 00:29:53.220
Tamara Bogdanovic: As well as the horizon agm.

185
00:29:56.280 --> 00:30:13.440
Tamara Bogdanovic: But I need to include to cautionary remarks basically our model and all these other models that are based on cosmological simulation simulation really place a lower limit on the laser detection rate.

186
00:30:14.550 --> 00:30:27.660
Tamara Bogdanovic: The reason being that the bulk of the Lisa detections will be of call essences of massive black hole binary is with mass less than 10 to the six or masters and for us that's basically the minimum.

187
00:30:28.680 --> 00:30:37.320
Tamara Bogdanovic: mass of a binary did we model in our model because we inherit the white population from the 2015.

188
00:30:38.670 --> 00:30:46.500
Tamara Bogdanovic: So we are placing a lower limit and, therefore, if the numbers in low down automatically be alarmed.

189
00:30:48.270 --> 00:30:56.730
Tamara Bogdanovic: The second cautionary remark is that I just told you moments ago that gastronomical friction seems to play a very important role.

190
00:30:58.320 --> 00:31:05.790
Tamara Bogdanovic: In basically driving massive Michael peers to merger, but in this calculation in the semi analytic model.

191
00:31:06.660 --> 00:31:26.550
Tamara Bogdanovic: Are in the results that I showed you this far, we did not take into account the effect of really the feedback from an accreting massive black hole or both of them on the gas, so we didn't really include that effect in our calculation of gases that i'm friction.

192
00:31:27.720 --> 00:31:32.010
Tamara Bogdanovic: And well we're going to talk about that affecting you in a moment.

193
00:31:35.490 --> 00:31:48.120
Tamara Bogdanovic: So let's try to connect the dots and see if we can predict the properties of dual agents that will eventually call us some will become liza sources.

194
00:31:49.410 --> 00:32:12.990
Tamara Bogdanovic: And what would that connection look like so in order to do that, we defined theoretical electromagnetic detectable So what is what is, in that the tech stability factor well for one we take into account the instantaneous separation or have to have the two.

195
00:32:14.160 --> 00:32:15.390
Tamara Bogdanovic: Massive whitehall's.

196
00:32:16.440 --> 00:32:32.610
Tamara Bogdanovic: Because if say you wish to detect a dual ign by taking an image, you will have an easier time detecting the DOJ Jan with largest separation, give them the angular resolution of your instrument.

197
00:32:33.900 --> 00:32:42.600
Tamara Bogdanovic: We also included the luminosity ratio of the two agm as a function of time because again if.

198
00:32:43.500 --> 00:32:56.190
Tamara Bogdanovic: You add ons if the two agents have comparable luminosity is it's going to be easier to tell them apart, then, if one is under luminous severely under rooms relative to the other and, of course, what matters is.

199
00:32:57.510 --> 00:33:04.440

Tamara Bogdanovic: A redshift or luminosity distance to the source, so we also include that in this integral.

200
00:33:05.520 --> 00:33:19.080
Tamara Bogdanovic: So i'm flooding and showing the this detective ability factor is a color in the panel on panels at the bottom so let's first look into left one that shows.

201
00:33:20.190 --> 00:33:27.420
Tamara Bogdanovic: The tech stability as a functional binary mass versus the call essence redshift for the two massive black holes.

202
00:33:28.470 --> 00:33:30.300
Tamara Bogdanovic: You can see that.

203
00:33:31.800 --> 00:33:46.710
Tamara Bogdanovic: Most of those no detectable doing yet should cluster at low rate shifts and again Hello binary masses just because the the system stem to leave and gas rich galaxies.

204
00:33:47.340 --> 00:33:58.860
Tamara Bogdanovic: They nicely overlapped with Lisa signal to noise contours so you could expect that most dual agency that you see and at any given redshift should be detected by these.

205
00:34:00.390 --> 00:34:20.220
Tamara Bogdanovic: are looking at the right panel it's basically a similar statement plot, and in terms of binary mass and mass ratio again, you see that most of these indeed detectable systems rupert's comparable mass ratio is not surprising, because for those you expect.

206
00:34:21.540 --> 00:34:41.130
Tamara Bogdanovic: To have two agents of comparable luminosity is too, so that will maximize our chromatic detect ability, so there is a nice overlap there Okay, so that gives you a handle if you wish to calculate basically a call us a stretch or a fraction of new ign that will eventually lead to emerge.

207
00:34:43.200 --> 00:34:43.740
Tamara Bogdanovic: Okay.

208
00:34:45.330 --> 00:34:48.360
Tamara Bogdanovic: So far, so good any any questions before.

209

00:34:51.330 --> 00:34:54.570
Sarah Jeffreson: I have a quick question that follows up with the previous one.

210
00:34:56.160 --> 00:34:56.670
Sarah Jeffreson: I think.

211
00:34:58.200 --> 00:35:01.590
Sarah Jeffreson: One of the issues that I wonder about is that.

212
00:35:01.740 --> 00:35:06.990
Sarah Jeffreson: you're seeing a lot of the merger times being very short there about 100 million years or so.

213
00:35:07.110 --> 00:35:07.530
Tamara Bogdanovic: ago I.

214
00:35:07.920 --> 00:35:16.470
Sarah Jeffreson: was working correctly, so it probably happens relatively fast after you're seated in the.

215
00:35:17.490 --> 00:35:24.270
Sarah Jeffreson: In the simulation so is that I mean this that comes that worry, you know.

216
00:35:26.490 --> 00:35:38.850
Tamara Bogdanovic: Okay, yes, so when we see is actually that times are relatively low, what can go back just for a SEC to that so here are the time scales.

217
00:35:39.870 --> 00:35:58.440
Tamara Bogdanovic: So the total time on the right hand side from killer par six skill is done to call lessons are actually for majority of our sample relative too long on the order of 10 to the 910 to the 10 to the nine years.

218
00:36:00.240 --> 00:36:05.490
Tamara Bogdanovic: So, as a consequence, really, what we see is that by the time they merge.

219
00:36:06.810 --> 00:36:09.300
Tamara Bogdanovic: The call, so this is really happened that low Richard.

220

00:36:10.830 --> 00:36:11.490
Tamara Bogdanovic: Just because.

221
00:36:12.630 --> 00:36:13.680
Tamara Bogdanovic: we're relatively long.

222
00:36:17.250 --> 00:36:26.790
Sarah Jeffreson: feeding is that super high adventure, you know, whatever where the HALO is forming and then they're taking the snapshot whether it's posted that can be.

223
00:36:26.850 --> 00:36:28.560
Tamara Bogdanovic: resolved in Alaska.

224
00:36:30.000 --> 00:36:38.700
Sarah Jeffreson: Right and I just sort of wondering, because the end up finding that depended the six or mass ones that are most detectable.

225
00:36:39.180 --> 00:36:39.870
Tamara Bogdanovic: tend to be a.

226
00:36:44.700 --> 00:36:54.630
Sarah Jeffreson: Comparable mass ratios, and since the start of entities are being seated as the star formation rate increases and universe, both of them are probably being seated right around right to.

227
00:36:54.810 --> 00:36:57.810
Sarah Jeffreson: To, then you know within.

228
00:36:59.040 --> 00:37:10.080
Sarah Jeffreson: A giga year they're all merged by Richard to one, so what we see it at Richard of zero in terms of the detective ability might be a small fraction of these things and really have the.

229
00:37:10.080 --> 00:37:17.340
Sarah Jeffreson: longest coalescence times and the longest the slowest practicing associate to.

230
00:37:18.360 --> 00:37:22.860
Sarah Jeffreson: reconcile how much of the other part of the curve, where the bulk of merging is happening is all.

231
00:37:22.890 --> 00:37:23.970

Sarah Jeffreson: determined by the.

232
00:37:24.570 --> 00:37:29.280
Sarah Jeffreson: assumptions in the simulation and not really by reality in some sense.

233
00:37:31.980 --> 00:37:37.650
Tamara Bogdanovic: Well, it does, I mean what matters is the total evolution time yes you're right about that.

234
00:37:38.850 --> 00:37:41.850
Tamara Bogdanovic: So it's basically from the incident in time where.

235
00:37:43.080 --> 00:37:59.970
Tamara Bogdanovic: The pair exists, like one or two killed parsecs separations separation times the delay time if you wish, or the merger that determines the redshift where they call us, you can see that a lot of them coalesce that's basically.

236
00:38:01.140 --> 00:38:09.900
Tamara Bogdanovic: redshift willow richards right, what is this corresponds to redshift was them 0.4.

237
00:38:10.590 --> 00:38:25.290
Sarah Jeffreson: Right, so I mean maybe we roll them at a different rate I love even more merging and go read that I was wondering whether that will be another way of making the making the lower limit that to the writing comes from a strong reward.

238
00:38:27.690 --> 00:38:30.090
Sarah Jeffreson: it's like a pencil on the road.

239
00:38:32.730 --> 00:38:40.680
Tamara Bogdanovic: Very gosh I cannot I didn't hear the entire sentence so i'm not sure I understood the question.

240
00:38:43.110 --> 00:38:47.130
Tamara Bogdanovic: I want to keep this for the end just because my my sound seems to be.

241
00:38:47.340 --> 00:38:49.710
Tamara Bogdanovic: Like just a little bit interrupted.

242

00:38:54.510 --> 00:38:56.730
Tamara Bogdanovic: Is it okay to keep this again.

243
00:38:57.090 --> 00:38:58.530
Sarah Jeffreson: we'll talk more at the end.

244
00:39:00.330 --> 00:39:00.630
Tamara Bogdanovic: Okay.

245
00:39:06.450 --> 00:39:07.710
Tamara Bogdanovic: Okay, so.

246
00:39:09.780 --> 00:39:15.570
Tamara Bogdanovic: So I told you a moment ago that the that the results that I showed you neglect the effect of.

247
00:39:16.680 --> 00:39:27.750
Tamara Bogdanovic: radiative feedback from a creating massive black holes so Okay, what happens if you actually take into account that effect what, what are the anticipated effects or.

248
00:39:29.400 --> 00:39:48.900
Tamara Bogdanovic: And i'm going to illustrate that by showing you these two animations and hopefully they will play on your end from two dimensional radiation fighter dynamic simulation of million supermassive black hole moving through some idealized uniform neutral background we do.

249
00:39:51.180 --> 00:39:59.070
Tamara Bogdanovic: From our work couple of years back, so the last panel shows number density that's the the color scheme.

250
00:39:59.520 --> 00:40:16.140
Tamara Bogdanovic: The right hand side panel shows the temperature of the gas around it and why call the black hole is Center that 00 coordinate and is moving with mark number of 2.7 relative to the bag or a medium, the size of the box is about 1.66.

251
00:40:17.970 --> 00:40:28.230
Tamara Bogdanovic: So the very moment when the black hole starts creating and the radiation is emitted from the basically enormous region surrounding the black hole.

252
00:40:29.460 --> 00:40:33.000

Tamara Bogdanovic: Or what we see is that this low density.

253
00:40:34.320 --> 00:40:39.840
Tamara Bogdanovic: Ionized region bubble basically forms around the black hole.

254
00:40:40.920 --> 00:40:48.060
Tamara Bogdanovic: it's a tier shaped region and it's about a size of one kilo per SEC in in the case of this.

255
00:40:50.250 --> 00:40:51.780
Tamara Bogdanovic: This particular setup.

256
00:40:52.830 --> 00:41:04.530
Tamara Bogdanovic: Now, why is that interesting well a, this means that a question on to the dash massive Bible will be suppressed because it's now surrounded by a hot low density.

257
00:41:05.490 --> 00:41:22.530
Tamara Bogdanovic: Gas and be our gravitational gas gas week that is exerting dynamical friction on to the black hole may be affected as well right because the radiation is basically sweeping away the gas around the black hole.

258
00:41:24.600 --> 00:41:35.850
Tamara Bogdanovic: If you actually calculate what is the region around the black hole massive black hole this mass that contributes most of the dynamical friction force.

259
00:41:37.290 --> 00:41:44.010
Tamara Bogdanovic: You would find that it's basically an overdose week that isn't closed within few parsecs from the black hole.

260
00:41:45.270 --> 00:41:53.640
Tamara Bogdanovic: Right few parsecs in the absence of radiated feedback, so you can see that this bubble being much larger than that.

261
00:41:54.720 --> 00:42:02.280
Tamara Bogdanovic: implies that is over dense gas week will be swept away by radiation certainly perturbed if not obliterated.

262
00:42:04.860 --> 00:42:07.320
Tamara Bogdanovic: Okay well with that in mind.

263
00:42:09.180 --> 00:42:12.750
Tamara Bogdanovic: i'll tell you that, by actually calculating explicitly.

264
00:42:14.280 --> 00:42:23.250
Tamara Bogdanovic: The gases that have little friction for us in this setup we find that the 3D to feedback renders it completely ineffective.

265
00:42:24.870 --> 00:42:44.640
Tamara Bogdanovic: And what i'm showing in this three panels here are basically snapshots from three different simulations one where the black hole is moving with a mark number of one half one where it's moving with number one and number two and again number density gas number density is what's shown.

266
00:42:45.840 --> 00:42:53.730
Tamara Bogdanovic: And what are you wanted to show you is not only that yes, dynamical friction is rendered ineffective in this scenarios.

267
00:42:54.660 --> 00:43:06.510
Tamara Bogdanovic: But in the second and third panel what you can see is that a shed upstream from the black hole, there is an over dance bow shock that is forming a kind of the black hole.

268
00:43:07.950 --> 00:43:13.860
Tamara Bogdanovic: And this over density and yes interact with the black hole and he actually accelerates.

269
00:43:15.420 --> 00:43:29.010
Tamara Bogdanovic: But there is no then sweep behind the black hole to kind of counteract that so contrary to the prediction of the classical gases dynamical friction, where you expect the weight behind the black hole to.

270
00:43:30.060 --> 00:43:39.900
Tamara Bogdanovic: This dollar it the black hole or SAP it's orbital energy what we find is that in presence radiating feedback the black hole actually is accelerated.

271
00:43:41.940 --> 00:43:42.750
Tamara Bogdanovic: So.

272
00:43:44.370 --> 00:43:48.900

Tamara Bogdanovic: That, of course, does not happen in every case and it doesn't.

273
00:43:50.100 --> 00:43:55.080
Tamara Bogdanovic: happen forever so Michael is not going to be accelerated, to the speed of light.

274
00:43:56.610 --> 00:44:07.440
Tamara Bogdanovic: There is a set of criteria that determine when they know gas dynamical friction is actually behaving as negative dynamical fridge.

275
00:44:08.820 --> 00:44:12.870
Tamara Bogdanovic: And you can see that set of criteria shown at the bottom.

276
00:44:14.730 --> 00:44:24.060
Tamara Bogdanovic: This happens when the mark number of the black hole is less than four this falls right from a straight from the jump conditions.

277
00:44:25.110 --> 00:44:26.370
Tamara Bogdanovic: Because for.

278
00:44:27.420 --> 00:44:41.250
Tamara Bogdanovic: Mark numbers higher than for this bow shock or dance beauchamp just is the standardized and it falls apart so you're back to effectively bondi who are littleton accretion and classical dynamical friction pitch.

279
00:44:42.600 --> 00:44:43.860
Tamara Bogdanovic: The second criterion.

280
00:44:45.120 --> 00:44:59.100
Tamara Bogdanovic: Basically, follows from the requirement that the radius of the Ionized region or the stronger and sphere, if you wish, is larger than the bondi radius or the radius of gravitational dominance of the black hole.

281
00:45:00.810 --> 00:45:01.740
Tamara Bogdanovic: In that case.

282
00:45:03.000 --> 00:45:08.190
Tamara Bogdanovic: Basically, the radiation leads to the formation of this large bubble.

283
00:45:09.390 --> 00:45:19.860
Tamara Bogdanovic: And you can see, in that criteria and, as it is written that it's basically a product of the black hole mouse, and the number density of the gas.

284
00:45:20.580 --> 00:45:33.120
Tamara Bogdanovic: At infinity where it's not perturbed basically by by the gravity of the black hole, and that that these two should basically be less than 10 to the nine Simon says per centimeter cube.

285
00:45:34.320 --> 00:45:53.250
Tamara Bogdanovic: So what this means is that negative dynamical friction will more strongly effect lower mouse black holes right, those are tend to the six or masses rather than tend to tonight because they will fall within this criterion that will satisfy this inequality more easily.

286
00:45:54.720 --> 00:46:03.720
Tamara Bogdanovic: So those massive black holes will have fewer means of reaching the Center or around the galaxy and merging with a with a counterpart black hole.

287
00:46:04.950 --> 00:46:12.390
Tamara Bogdanovic: And these of course are exactly the massive black holes, there are of interest to Lisa rotation wave observatories Observatory.

288
00:46:14.490 --> 00:46:14.850
Tamara Bogdanovic: Okay.

289
00:46:19.290 --> 00:46:19.920
Tamara Bogdanovic: Moving on.

290
00:46:22.830 --> 00:46:28.380
Tamara Bogdanovic: So, how does this affect the murder rates, then we calculate so if we fold.

291
00:46:29.460 --> 00:46:33.960
Tamara Bogdanovic: The effect of radiative feedback where we find that.

292
00:46:35.280 --> 00:46:38.910
Tamara Bogdanovic: There is negative dynamical friction force that accelerates the black hole.

293
00:46:40.290 --> 00:46:47.160
Tamara Bogdanovic: And we recalculate the cosmological murder rates for my supervisor calls in this sample that we consider.

294
00:46:47.730 --> 00:47:08.280
Tamara Bogdanovic: And leader detection rates, this is what we find so, starting with the Left panel again, this is the differential coalescence rate shown in terms of the binary mass and redshift or call essence, you can now see that most of the call essences happen at higher binary masses.

295
00:47:09.750 --> 00:47:21.630
Tamara Bogdanovic: are so it used to be that lower Mars binaries were greatly helped by gas dynamical friction before when we did not consider the the radio, the feedback now, when we take it into account.

296
00:47:21.960 --> 00:47:34.620
Tamara Bogdanovic: Those the mergers of those low mass binaries are affected by negative dynamical friction and what we see is that murder rates speak at a higher masses of templates are masters.

297
00:47:36.060 --> 00:47:46.560
Tamara Bogdanovic: And these now the the Court pixels now don't line up necessarily with Lisa signal to noise ratio contours.

298
00:47:48.240 --> 00:47:54.960
Tamara Bogdanovic: So I mean it means that Lisa would not necessarily see most of those murders, because those bibles are two massive.

299
00:47:57.900 --> 00:48:07.200
Tamara Bogdanovic: Similar is the case for the second panel, where you see the differential murder rate in terms of the binary mass and mass ratio.

300
00:48:08.370 --> 00:48:20.790
Tamara Bogdanovic: Lisa will pick up some because the signal to noise ratio of eight kind of encloses some fraction mergers, but most will actually be out of reach for these.

301
00:48:23.400 --> 00:48:24.420
Tamara Bogdanovic: And on the.

302
00:48:25.980 --> 00:48:35.640

Tamara Bogdanovic: On the right the last panel shows differential coalescence rate in terms of the stellar bulge mass and the destruction of around the galaxy.

303
00:48:36.840 --> 00:48:44.760
Tamara Bogdanovic: You can now see that the peak of the cosmological murder rate is located.

304
00:48:46.740 --> 00:48:50.700
Tamara Bogdanovic: Basically, add values of higher standard large mass.

305
00:48:52.620 --> 00:49:11.910
Tamara Bogdanovic: and very low gas fractions because these galaxies are not affected by negative than our reflection, if there is no gas there's no negative gases dynamical friction, so these systems merge entirely due to the effect of physically stellar processes, acting on on the two black holes.

306
00:49:13.470 --> 00:49:14.010
Tamara Bogdanovic: and

307
00:49:15.270 --> 00:49:28.350
Tamara Bogdanovic: These massive systems actually will be out of rituals right because it mostly will be the decking lauren mass murders so just to to summarize what is that we calculate.

308
00:49:29.100 --> 00:49:41.010
Tamara Bogdanovic: When we take into account the effect of radiative feedback, as we know it from simulations news, for we find the cosmological murder rate about 0.1 per year.

309
00:49:42.270 --> 00:49:48.720
Tamara Bogdanovic: And it leaves a detection rate, which is much lower it's now point oh to prayer.

310
00:49:49.740 --> 00:49:57.870
Tamara Bogdanovic: And this at first, maybe alarming because if Lisa flies for even for maybe even 10 years that indicates, less than one event.

311
00:49:59.490 --> 00:50:00.060
Tamara Bogdanovic: i'm.

312
00:50:01.110 --> 00:50:15.300

Tamara Bogdanovic: detected by Lisa but, again, I will just remind you that are, this is a lower limit so we're not making a prediction that Lisa will not see anything we are not but.

313
00:50:16.320 --> 00:50:26.940
Tamara Bogdanovic: What we are seeing is that radiated feedback if you operate in a way that we see in simulations we and some other groups that we may make a difference, it may make a dent in these.

314
00:50:27.690 --> 00:50:36.060
Tamara Bogdanovic: Detection rates, just to remind you what is, what are the numbers that we calculated in the absence of really the feedback I showed the line at the bottom.

315
00:50:37.380 --> 00:50:40.500
Tamara Bogdanovic: So those are the rates that we calculated.

316
00:50:43.620 --> 00:50:45.300
Tamara Bogdanovic: And I showed you before OK.

317
00:50:47.820 --> 00:50:50.280
Tamara Bogdanovic: OK so rated feedback matters.

318
00:50:51.330 --> 00:51:04.680
Tamara Bogdanovic: It may make a big impact, so this is my final slide let me show you basically now now, we learned something about the properties will delay GS that will eventually.

319
00:51:05.070 --> 00:51:14.490
Tamara Bogdanovic: lead to coalescence of massive black holes and some of them, maybe even become liza sources are let's see what is the fraction of those that that.

320
00:51:15.300 --> 00:51:26.850
Tamara Bogdanovic: call us so that, if we measure some number of dual agents on the sky, we can basically in statistical sense predict whether coalescence.

321
00:51:27.720 --> 00:51:39.000
Tamara Bogdanovic: cosmological coalescence rate of monster boys causes so on the Left coalescence fractions are showing versus the redshift and which dual agency serves Earth.

322
00:51:40.800 --> 00:51:48.930

Tamara Bogdanovic: It killed parsecs separations and this first left panel is for the calculation, without any effect of radiating feedback.

323
00:51:50.220 --> 00:52:08.670
Tamara Bogdanovic: We basically make a cut made a cut in terms of the volumetric luminosity, which is the only one that we can measure or or model rather proportional to the equation that rate on to the massive black holes and we find that let's first look at the the.

324
00:52:09.720 --> 00:52:20.010
Tamara Bogdanovic: The blue curve here the blue curve represents dual agency that separation about 400 parsecs so if we look at redshift have to say.

325
00:52:21.030 --> 00:52:30.210
Tamara Bogdanovic: We find that any new agents that redshift have to that have separation of 400% should pretty much be march bi directional zero.

326
00:52:31.710 --> 00:52:43.410
Tamara Bogdanovic: And the same is true for obviously do all agents with smaller separations like 100 or six but moving on to larger separations it takes longer time.

327
00:52:44.580 --> 00:52:56.460
Tamara Bogdanovic: For say do all that separation of seven 706 to merge, so we see that it's only a fraction about 70 to 80% of them that merge by the retroactive zoo.

328
00:52:58.530 --> 00:52:59.010
Tamara Bogdanovic: and

329
00:53:00.930 --> 00:53:09.540
Tamara Bogdanovic: At the bottom, the Red curve shows basically this fraction for all possible pairs and simulation.

330
00:53:11.280 --> 00:53:14.400
Tamara Bogdanovic: In the presence of Radio to feedback, the picture changes, a little bit.

331
00:53:16.110 --> 00:53:22.500
Tamara Bogdanovic: Again coalescence fraction versus the redshift of a precursor to all ign.

332
00:53:24.090 --> 00:53:27.870

Tamara Bogdanovic: shows that now at redshift have to.

333
00:53:29.220 --> 00:53:34.740
Tamara Bogdanovic: We don't see any dual agm stare at redshift have to that have separation 136.

334
00:53:35.850 --> 00:53:38.130
Tamara Bogdanovic: Because, in the presence of radio, the feedback.

335
00:53:39.240 --> 00:53:47.550
Tamara Bogdanovic: or massive Bible periods of all very slowly, they really don't reach such a small separations so we don't have any in our sample.

336
00:53:51.240 --> 00:54:10.800
Tamara Bogdanovic: When it comes to the blue squares separation 400 parsecs we have some of those, but they also only a small fraction that redshift have to will evolve to coalescence down to redshirt him zero even if their separation is only 400 parts.

337
00:54:11.850 --> 00:54:29.280
Tamara Bogdanovic: And you can see, basically, the rates or the coalescence fraction being even lower for those new agey on aggression to that have a separation of 700 parsecs only about 20% of those will all two courses and the red curve shows the total for all possible separations.

338
00:54:31.110 --> 00:54:31.680
Tamara Bogdanovic: So.

339
00:54:33.570 --> 00:54:47.640
Tamara Bogdanovic: If indeed the nature operates in this way, then we can use predictions like this from theoretical models to convert the number of observed all the years of the sky.

340
00:54:48.930 --> 00:54:56.010
Tamara Bogdanovic: To some expectations for cosmological coalescence rating, perhaps even Lisa detection rates.

341
00:54:58.260 --> 00:55:02.520
Tamara Bogdanovic: So we're almost out of time, Paul put up my summary of.

342
00:55:03.600 --> 00:55:12.000

Tamara Bogdanovic: Dual a GS remained the most explicit observational evidence for massive black hole peers, that we have, at this point in time and.

343
00:55:13.050 --> 00:55:23.250
Tamara Bogdanovic: It would be great if we can actually use them to make predictions for the rate of mergers massive white holes in the universe.

344
00:55:24.630 --> 00:55:39.990
Tamara Bogdanovic: With calculations that connect to nature and properties will do all ids and to call essences we can't cautiously use them to infer the call essence rates being being aware of caveats and our.

345
00:55:41.010 --> 00:55:44.640
Tamara Bogdanovic: inadvertently limited knowledge right in theoretical models.

346
00:55:46.230 --> 00:55:52.890
Tamara Bogdanovic: We find it for a population of massive black hole pairs that actually call us within the hubble time or, more importantly, by wretched zero.

347
00:55:53.460 --> 00:56:02.340
Tamara Bogdanovic: dynamical friction, is the most important mechanism that determines their murder rate so that's interesting that is interesting, and it means that.

348
00:56:02.640 --> 00:56:11.820
Tamara Bogdanovic: When call essence rate is measured by gravitational waves of your rotation way observatories for a population of massive black holes, the day.

349
00:56:13.530 --> 00:56:15.510
Tamara Bogdanovic: That rate will directly.

350
00:56:17.370 --> 00:56:30.240
Tamara Bogdanovic: constrain the efficiency of dynamic of friction so for the first time perhaps we'll be able to test this theoretical concept, because that's what they now call friction is at this point.

351
00:56:31.410 --> 00:56:35.460
Tamara Bogdanovic: it's basically theoretical construct that is yet to be tested through observations.

352
00:56:37.110 --> 00:56:48.720
Tamara Bogdanovic: Without really any feedback or model predicts the a merger rate that is about the half and Lisa detection rate that is slightly lower than that this is comparable to.

353
00:56:50.040 --> 00:56:58.740
Tamara Bogdanovic: To works in the literature, most of the measures in our calculation originate from the mass range of 10 to the six to 10 to the seven but.

354
00:56:59.760 --> 00:57:08.790
Tamara Bogdanovic: Again, my cautionary remark is that is because we don't capture the evolution of black holes that have mass lower than six.

355
00:57:09.990 --> 00:57:10.470
Tamara Bogdanovic: and

356
00:57:12.510 --> 00:57:17.940
Tamara Bogdanovic: The peak of the call essences happens at ratchet around to.

357
00:57:19.740 --> 00:57:21.420
Tamara Bogdanovic: Anything and poor for Lisa.

358
00:57:22.710 --> 00:57:29.220
Tamara Bogdanovic: We calculate that most of those detection should happen that signal to noise ratio about 100 which is pretty loud police.

359
00:57:30.240 --> 00:57:31.380
Tamara Bogdanovic: would really the feedback.

360
00:57:32.400 --> 00:57:40.290
Tamara Bogdanovic: We find a striking reduction or the binary coalescence rate cosmological core essence rate by a factor of 78%.

361
00:57:41.490 --> 00:57:50.490
Tamara Bogdanovic: And even more dramatic reduction of a visa detection rate by 98% as well as a reduction in signal to noise ratio.

362
00:57:52.140 --> 00:58:05.820
Tamara Bogdanovic: So I don't want to be alarmist, but my conclusion is that the that it's important to understand the effect of radiative feedback on the Lisa carson's rate.

363
00:58:07.110 --> 00:58:11.640
Tamara Bogdanovic: or detection rate, because it may be important make me make a difference.

364
00:58:12.750 --> 00:58:15.720
Tamara Bogdanovic: So i'll stop there, thank you very much for.

365
00:58:15.810 --> 00:58:16.170
Sarah Jeffreson: Thank you.

366
00:58:17.190 --> 00:58:20.640
Tamara Bogdanovic: For your attention i'm happy to take any questions.

367
00:58:22.140 --> 00:58:36.570
Sarah Jeffreson: um so we're at the hour, but summer, if you have five more minutes to stay, I see there's at least some questions online Dan you can go ahead and unmute you know if you have to leave at this point.

368
00:58:37.830 --> 00:58:49.320
Dan Schwartz: yeah thanks for teaching me a lot about coalescing black holes, without waiting for Lisa if we measured like a distribution of.

369
00:58:50.370 --> 00:58:52.170
Dan Schwartz: A pair separations.

370
00:58:53.490 --> 00:59:15.330
Dan Schwartz: Might you or have you predicted what that distribution might be, and it seems like separations less than a killer par secor especially important for to see how pairs have coalesced from their initial formation down toward merging and where they might stop.

371
00:59:16.830 --> 00:59:21.000
Tamara Bogdanovic: Right rises So yes, in principle, we can.

372
00:59:22.560 --> 00:59:41.160
Tamara Bogdanovic: We can make predictions for distribution of separations in in this model, our model basically looks at separations lower than one or two kill parsecs mostly because, by then, we expect the two stellar ball just to merge into one, so this is when we expect the dynamical friction should.

373
00:59:42.210 --> 00:59:48.480

Tamara Bogdanovic: start being important rather than title larger scale title interactions or the two galaxies.

374
00:59:50.280 --> 00:59:54.150
Tamara Bogdanovic: So, in order to basically test this picture.

375
00:59:55.290 --> 01:00:06.030
Tamara Bogdanovic: We would need a reasonably large statistically representative sample of dual agency within separations that are lower than a few kill parsecs.

376
01:00:08.820 --> 01:00:14.010
Tamara Bogdanovic: So yeah Hopefully there are already some detections a number of.

377
01:00:15.960 --> 01:00:24.180
Tamara Bogdanovic: Dual agents are available, but not yet a full statistical sample that we could use to dissect them like this basically.

378
01:00:25.590 --> 01:00:28.440
Tamara Bogdanovic: Make predictions about coalescence rates and so on.

379
01:00:31.770 --> 01:00:33.750
Sarah Jeffreson: I have a question about you're ready to.

380
01:00:33.750 --> 01:00:52.080
Sarah Jeffreson: feedback and do you have a sense that what eddington ratio, you would need for this to have a significant effects my intuition, is that an offset by co would probably have a lower income rate and would probably turn into a relatively inefficient disk anyway so maybe this isn't too catastrophic.

381
01:00:55.980 --> 01:00:56.730
Tamara Bogdanovic: So.

382
01:01:01.170 --> 01:01:03.060
Tamara Bogdanovic: i'm trying to.

383
01:01:06.900 --> 01:01:08.400
Tamara Bogdanovic: Remember.

384
01:01:09.930 --> 01:01:20.160

Tamara Bogdanovic: So your question is, what is the what is the adding to luminosity and which this effect negative dynamical friction.

385
01:01:21.240 --> 01:01:21.660
Sarah Jeffreson: Right.

386
01:01:22.740 --> 01:01:27.810
Sarah Jeffreson: yeah it doesn't need to be you know, an agm levels and potentially Does that mean, could we.

387
01:01:27.810 --> 01:01:30.960
Sarah Jeffreson: Even group is that observation, we it's a migration.

388
01:01:32.520 --> 01:01:33.120
Tamara Bogdanovic: So.

389
01:01:34.500 --> 01:01:40.680
Tamara Bogdanovic: There is no single specific value that I can give you, but I can tell you that.

390
01:01:41.880 --> 01:01:52.920
Tamara Bogdanovic: What simulations are creating massive rifles or or any by false intermediate mouse are finding is that when radiative feedback is effective.

391
01:01:53.490 --> 01:02:05.550
Tamara Bogdanovic: That suppressing a Christian when it's effective at creating this kind of ios mobile yeah accretion rate for the black hole is reduced by a factor about 100.

392
01:02:06.570 --> 01:02:10.020
Tamara Bogdanovic: relative to the scenario when there is no ready to feedback.

393
01:02:11.910 --> 01:02:12.660
Tamara Bogdanovic: So.

394
01:02:13.680 --> 01:02:30.960
Tamara Bogdanovic: Basically, a scenario where when there is no rain at feedback is you know, whatever luminosity whatever baseline luminosity you start with in the presence of Radio to feedback, it will be about 100 a factor hundred lower and so will be indeed.

395

01:02:32.130 --> 01:02:34.500
Tamara Bogdanovic: even lower if you started adapting to me would be.

396
01:02:35.430 --> 01:02:36.120
Sarah Jeffreson: Hundreds of.

397
01:02:36.510 --> 01:02:38.160
Tamara Bogdanovic: Adding to that point.

398
01:02:39.720 --> 01:02:46.560
Tamara Bogdanovic: So yeah you're right in in maybe that for some systems, there will be asked, it will be reduced.

399
01:02:48.120 --> 01:02:52.830
Tamara Bogdanovic: sufficiently so that there would be radiating inefficient accretion region.

400
01:02:57.510 --> 01:03:03.600
Sarah Jeffreson: Thanks, well, we should probably stop there, thank you so much for a really thought provoking talk.

401
01:03:04.530 --> 01:03:22.410
Sarah Jeffreson: I think it's going to be amazing to see how the mass distributions that we you know uncover whether they something I took was you know they encode the underlying masters solution, but they also include all this physics, of what actually merges as opposed to just what sort of stays separate.

402
01:03:24.870 --> 01:03:25.260
Sarah Jeffreson: In a.

403
01:03:25.680 --> 01:03:26.820
Sarah Jeffreson: Really amazing to see.

404
01:03:28.350 --> 01:03:39.660
Tamara Bogdanovic: Well, thank you very much for for your attention and for your questions feel free to email me if you can cover whoops any other questions in the meantime.

405
01:03:39.930 --> 01:03:41.400
Sarah Jeffreson: amazing Thank you so much.