

WEBVTT

1

00:00:06.660 --> 00:00:07.319

Morgan Elowe MacLeod: Of the Lego

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00:00:08.790 --> 00:00:10.830

Morgan Elowe MacLeod: Lego scientific collaboration. Thank you.

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00:00:11.849 --> 00:00:12.750

Morgan Elowe MacLeod: And

4

00:00:14.070 --> 00:00:31.230

Morgan Elowe MacLeod: His he's an expert in numerical relativity and especially intermediate mass black holes, which we're going to learn about today and conveniently they've been in the news recently. So I'm I'm even more excited than I would be otherwise.

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00:00:32.280 --> 00:00:40.470

Morgan Elowe MacLeod: To hear about it. In addition, Karen's received a number of accolades and awards along the way. He's a recipient of the Sam Nunn fellowship

6

00:00:41.610 --> 00:00:58.830

Morgan Elowe MacLeod: A postdoc of the Year award from Vanderbilt University and the Forbes 30 under 30 scientists list. So we're really very lucky to have him today and and we look forward to your talk. So Karen, you can go ahead and share your screen directly

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00:01:01.980 --> 00:01:03.270

Karan Jani: See if I can

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00:01:06.750 --> 00:01:12.420

Karan Jani: Well, first of all, thank you so much for having me here at ITC it's been a real honor and

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00:01:12.420 --> 00:01:16.260

Morgan Elowe MacLeod: Can I interrupt you. Sorry, I will play a bell sound.

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00:01:17.400 --> 00:01:19.200

Morgan Elowe MacLeod: When there's about five minutes left.

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00:01:19.350 --> 00:01:21.240

Karan Jani: Okay. All right. That's, that's fine.

12

00:01:22.680 --> 00:01:23.010

Okay.

13

00:01:24.060 --> 00:01:28.740

Karan Jani: So yes, thank you for having me. I think it's a it's just happens to be a very timely.

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00:01:29.850 --> 00:01:39.720

Karan Jani: Topic and talk that I'm excited to share just last week, we announced the detection of new gravitational wave event.

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00:01:40.470 --> 00:01:49.590

Karan Jani: Like oh, and we're gonna have announced number of gravitational wave events so far on each breaking one record or the other but this one is close to

16

00:01:50.130 --> 00:02:05.730

Karan Jani: Personally to me for the course. This has been one of my main roles within the lack of collaboration. And it's also a very unique astrophysical source. I hope I'm in the next 1020 minutes I was able to convince you on the same

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00:02:06.990 --> 00:02:15.630

Karan Jani: So those were catching up with this news are on May 21 2019 we send an alert.

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00:02:16.110 --> 00:02:33.870

Karan Jani: That there was a signal detected by the logo and the boat like detectors in the United States and the word good detector in Europe, those who have signed up for this gravitational wave triggers. If you have an app, you will get a notification on your app when whenever the signal is sent.

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00:02:34.890 --> 00:02:45.990

Karan Jani: The signal we released the sky map. And I'll talk a little about you know how other astronomers have followed timer. But typically, you know, this creates this is tweet electromagnetic follow up.

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00:02:47.850 --> 00:02:54.330

Karan Jani: Just last year around this time I was at Harvard now putting the physics department and also the ITC and

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00:02:54.900 --> 00:03:12.720

Karan Jani: Was by this September of last year and editorial team had been formed to start describing what this discovery is it took us about 15 months to finally announced that we have seen what we have seen on September 2 2020

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00:03:14.580 --> 00:03:25.200

Karan Jani: Back then, when we had, we had, we had started working on the paper. It was this thing that an exciting press conference will await where we will be able to say this with much fanfare

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00:03:25.800 --> 00:03:36.360

Karan Jani: As the time it does, we announced it over a zoom call just like this. But it was still a press release we the announcement happened from the European Gravitational Wave Observatory.

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00:03:37.050 --> 00:03:47.520

Karan Jani: With the Parkers partners from the word go expert collaboration. I was the representative there, on behalf of the Lego scientific cooperation, which is constitutes off about

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00:03:48.870 --> 00:03:52.530

Karan Jani: 90 universities from at 18 countries.

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00:03:53.610 --> 00:04:01.050

Karan Jani: The three colleagues of mine V3 were part of the editorial team that published two papers that were released on September 2

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00:04:01.470 --> 00:04:12.300

Karan Jani: One was published in the Astrophysical Journal letters on describing the astrophysical implications of the source and the other was published in the Physical Review Letters are describing more sort of discovery.

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00:04:13.020 --> 00:04:27.480

Karan Jani: And there's a lot of things which has been covered in this two papers which I would not have unfortunately time to chat, but can discuss moreover slack with we had to summarize the discovery in perhaps one sentence.

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00:04:28.560 --> 00:04:41.520

Karan Jani: Is what the New York Times had its on its cover story that this black holes shouldn't exist but there they are. And I think that is one of the reasons I would you know

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00:04:42.330 --> 00:05:00.000

Karan Jani: In retrospect, we look, it took us a while because we had to do a series of confirmation almost unusual for all other gravitational we once we have seen till date, just because of the claims that we were getting worse. So quote unquote to wild one more thing I liked specially about this.

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00:05:01.230 --> 00:05:09.720

Karan Jani: The Times article state did not use an artistic the repression of what is black elsewhere, but an actual solution of Einstein's equation.

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00:05:10.260 --> 00:05:25.620

Karan Jani: This abstract simulation was was from our group, you can see what we actually text is not any light around the two black holes. Although, those are the more famous pictures. You also don't see any gravitational lensing around them. All we see is just the one dimensional

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00:05:27.060 --> 00:05:30.210

Karan Jani: Version of the three dimensional gravitational wave which is released.

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00:05:31.740 --> 00:05:41.760

Karan Jani: The other thing here, I just want to because it's something which has missed usually is the size of the event horizons, which is placed here is the actual size of the two black holes.

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00:05:42.720 --> 00:05:52.530

Karan Jani: Compared to the gravitational wave amplitude. So the fact that we see this few hundred kilometer wide objects from literally halfway across the universe. It's just by itself so mind boggling.

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00:05:54.330 --> 00:06:05.670

Karan Jani: So what makes this particular discovery challenging was the very gravitational wave morphology. This is the shortest signal we have seen in the Ligo and Virgo detectors still date.

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00:06:06.390 --> 00:06:15.510

Karan Jani: The overall signal only lasted about point one seconds. And that is because Ligo is sensitive in a particular frequency band and the heavier the Black Codes.

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00:06:16.260 --> 00:06:22.230

Karan Jani: So, the lower the gravitational waves. They will not frequency, the climate. So we only saw about four cycles.

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00:06:22.950 --> 00:06:29.940

Karan Jani: Beyond the 30 Hertz limit that once the detector is in the sensitivity pan. You can see the picture on the left is this

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00:06:30.720 --> 00:06:41.430

Karan Jani: This plot that is usually released with all gravitational wave discoveries. The, the yellow line there is what the solution from recap from the Einstein's general relativity

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00:06:42.000 --> 00:06:57.930

Karan Jani: The blue line or the purple line is if you want to reconstruct the signal without assuming any model like completely independent morphology, yet we can see the signal has a false alarm rate of about one over 5000 years so you know this is not a background noise of any sort.

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00:06:58.980 --> 00:07:08.400

Karan Jani: The. The event was particularly seen by what we call an unmoderated burst search because if you see this time frequency map in the bottom panel.

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00:07:08.880 --> 00:07:17.130

Karan Jani: To see it's a blog. It's not like the usual curve that we are tend to see in gravitational wave. It's a literally a blog and this is what we search for in the data.

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00:07:17.880 --> 00:07:26.100

Karan Jani: This is particularly powerful to look for a very massive black holes like intermediate mass black holes part of my PhD thesis was to

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00:07:26.610 --> 00:07:36.960

Karan Jani: Train this kind of a search. We've been using this. I've been particularly running this even before LIGO made its first gravitational wave discovery. So what are the time on the search has really award.

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00:07:37.680 --> 00:07:46.710

Karan Jani: He have done a full search for intermediate mas black holes, since every observing off lygo I was one of the lead authors on those papers as well.

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00:07:47.550 --> 00:07:56.370

Karan Jani: And the fact that we did not see it all this now makes us event, particularly rare. We are already set astrophysical upper limits on this class, of course.

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00:07:56.790 --> 00:08:03.900

Karan Jani: The current rate is we will see only one such event in every eight years in a cubic meter per second volume which is 500 times less

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00:08:04.560 --> 00:08:13.440

Karan Jani: Than what you expect for regular binary black hole mergers that we have seen too late. Also, fun fact, two signals were detected on that day just four hours apart.

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00:08:13.890 --> 00:08:23.070

Karan Jani: Before theorists want to make any claim, those two are absolutely not related. We have looked around and they come from different parts of sky but the universe was particularly generous. On May 21

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00:08:24.510 --> 00:08:31.620

Karan Jani: Now the striking feature of this discovery is the masses are unusually high for the two black holes.

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00:08:31.980 --> 00:08:42.480

Karan Jani: We have used three state of the art general relativity signal models that can have the gravitational wave form from a binary black hole coalescence that is the inspiring merger and bring down

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00:08:42.810 --> 00:08:48.330

Karan Jani: On this models take into account all possible you know systems, including the precession of the orbits.

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00:08:48.960 --> 00:08:56.880

Karan Jani: The gravitational radiation beyond the quadruple autumn very in one of some of the most evil analysis we have done for any event till date.

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00:08:57.330 --> 00:09:13.920

Karan Jani: We further compared with 3000 about numerical relativity simulations, like the first visualization that I show from the times for you. It's a simulation is about five 500,000 50,000 hours of computing time. So in some of the world's fastest supercomputers.

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00:09:15.150 --> 00:09:22.770

Karan Jani: We had the resources because of what are the time many such catalogs have been made public, including one that I grew up and I published in 2016

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00:09:23.580 --> 00:09:32.850

Karan Jani: All of this consistent analysis. Later, we can confirm and say that both primary and secondary black hole that made this collision.

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00:09:33.150 --> 00:09:37.110

Karan Jani: is heavier than anything we have seen so far in gravitational wave astronomy.

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00:09:37.500 --> 00:09:45.450

Karan Jani: The plot on the left, gives you a representation three models three contours referred to the word three models thing the masters of the night calls are

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00:09:45.810 --> 00:09:52.860

Karan Jani: Xx has been the bigger black hole of the two white has been the smaller and one of them to the red triangle. I've drawn just as

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00:09:53.760 --> 00:10:02.970

Karan Jani: A reference. This is where all the Lego black holes like over Michaels would be that we have seen so far, you know, under that triangle box. So this really stands out.

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00:10:03.570 --> 00:10:07.170

Karan Jani: Now a thick rich, I want to specifically mentioned here is in

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00:10:07.860 --> 00:10:17.160

Karan Jani: Most work. I mean, through press release or otherwise and abstract. We will record that the mass of black hole is 85 and 66 which is the median value of what we get the mass

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00:10:17.670 --> 00:10:20.640

Karan Jani: But everything that is within the contours consistent with the signal.

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00:10:20.970 --> 00:10:31.290

Karan Jani: So if you have a model that says a black hole should be 60 solar mass or 100 sold them as well. We find both of them to be consistent, the median value is favored a certain value. We just want to highlight on that part.

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00:10:31.710 --> 00:10:37.560

Karan Jani: Of the father thing that the binary is fairly equal mass on so that tells us a bit about its formation channels.

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00:10:39.330 --> 00:10:50.640

Karan Jani: So while we do the analysis, we are oblivious to any astrophysics, we don't take into account any astrophysical modeling of what the source is but the implications of why this was such a big deal is.

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00:10:51.240 --> 00:10:58.950

Karan Jani: That the two black holes that collided are in what is called the so called pair instability supernova masacara.

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00:11:00.090 --> 00:11:09.000

Karan Jani: The idea is somewhat reflected in this plot. So if you had a star and that collapses and forms of compact object during supernova. There is a certain mass loss that will happen.

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00:11:09.390 --> 00:11:19.620

Karan Jani: So if you had about a 20 solar masses 08 main sequence, it will form of five solar mass Blackwood the higher does the serum admin second star is

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00:11:20.250 --> 00:11:26.520

Karan Jani: The size of the black hole would depend on the mat eliciting so the low metal is City Stars would end up making bigger black holes.

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00:11:27.270 --> 00:11:40.530

Karan Jani: What we find here is that provided this recipe of instability which softens the equation of state and create this electron positron pair at the time of supernova. So it leaves no remnant behind

73

00:11:41.040 --> 00:11:48.630

Karan Jani: That we should not expect anything in that certain mask app. This to black holes have a high probability of being part of it.

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00:11:49.650 --> 00:12:00.030

Karan Jani: You can see that the the violin plots on the left panel are the two black dots are what the black holes primary and secondary were and the red is what happens after merger.

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00:12:00.810 --> 00:12:10.740

Karan Jani: The only other way we could have formed it if there is no parent stability is one of the earlier triangles makes this black box again if you compute the probability the

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00:12:11.850 --> 00:12:15.570

Karan Jani: Secondary black hole ominous the parents simply limit is fairly vague.

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00:12:16.200 --> 00:12:23.190

Karan Jani: We don't know where it starts with it starts at 50 whether it's at 65 you know what it is. If the binary is the stars and one is binary

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00:12:23.580 --> 00:12:33.180

Karan Jani: But roughly, it could be anywhere from six to 46% of the smaller black hole is also in the pad instability Moscow. So that's a major conclusion we can choose from the masters of the system.

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00:12:34.050 --> 00:12:43.650

Karan Jani: The other evidence we have is for the spins. Now it's a bit, it's a sort of interesting that we only see four cycles, but the way gravitational wave

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00:12:44.520 --> 00:12:53.940

Karan Jani: Morphology is it's so sensitive to a many things that is internal. Do you know to the event horizon. So if the event horizon is spinning because both the black holes are called black holes.

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00:12:54.540 --> 00:13:05.580

Karan Jani: It leaves a particular morphology in the signal we find mile evidence that both the black holes exhibited spin orbit precession just before the merger.

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00:13:06.240 --> 00:13:15.870

Karan Jani: Or why does interesting is, then that means maybe the black holes, who are dynamically capture and that's why they're spins are not aligned with the orbital angular momentum of the access

83

00:13:16.320 --> 00:13:26.130

Karan Jani: Blood on the left is the sort of spin this plot we show you know to tell where the expense of the two black holes are even looked at the evidence that what if the system is not spinning at all.

84

00:13:26.880 --> 00:13:32.250

Karan Jani: We find strong evidence that the system is spinning, for sure. So those are the quick things on spins.

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00:13:33.510 --> 00:13:40.170

Karan Jani: Now comes the most interesting part to me, which is that the margin has produced when the two blackouts collide. IT WILL IS IS

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00:13:40.560 --> 00:13:46.800

Karan Jani: Intense gravitational wave. This one really is a eight solar Marcy square of gravitational radiation, making it one of the most energetic

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00:13:47.160 --> 00:13:52.050

Karan Jani: Events in the universe. Since Big Bang. It is definitely the most energetic event in gravitational wave astronomy.

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00:13:52.800 --> 00:14:00.600

Karan Jani: So the final black hole is smaller than the total mass, but it is still about 100 hundred solar masses about 1040 solar masses.

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00:14:01.110 --> 00:14:05.940

Karan Jani: Making it the first direct observational evidence of intermediate mas black hole.

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00:14:06.420 --> 00:14:12.750

Karan Jani: And I have to put an asterix here because the definition of intermediate most black hole is perhaps from gravitational waves side is different.

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00:14:13.170 --> 00:14:25.710

Karan Jani: Because Lego is not sensitive to the 10,000 solar mass intermediate Masako that the Astronomy community is more used to but still anything about hundred we've I think we can now start calling light I'm VHS. If not, I am BH to begin with.

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00:14:27.150 --> 00:14:32.910

Karan Jani: The other thing we can infer, is that the black hole is spinning at about 72% of its theoretical limit the final Blackwood

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00:14:33.390 --> 00:14:41.130

Karan Jani: And we have also measured the ring downs is the only second time we have seen one of the ring down modes, they have been for the mass independently and we get the same answer in both

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00:14:42.840 --> 00:14:51.000

Karan Jani: Moving on. This is the farthest gravitational waves signal we have seen the ratchet can be anywhere from point five to 1.1 there is a strong

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00:14:52.050 --> 00:14:53.610

Karan Jani: Impact of the bell has rung.

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00:14:54.870 --> 00:14:56.970

Karan Jani: One thing I would say is there is a claim.

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00:14:57.210 --> 00:14:58.890

Karan Jani: For electromagnetic counterpart.

98

00:14:59.130 --> 00:15:08.820

Karan Jani: By the CTF team, the masses that the distance that we get is that is twice farther than that. There is one model that has a mile evidence, but I can speak about it later.

99

00:15:10.500 --> 00:15:16.740

Karan Jani: Is this the only intermission most black Orpheus in in Lego so far. Well, no, we have seen other candidates. They are not as

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00:15:17.400 --> 00:15:27.720

Karan Jani: Dominant as this signal is but other another one GW 1705 go to that one of my undergraduate students and I we published our which also released on the same date September 2

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00:15:28.500 --> 00:15:37.530

Karan Jani: has amassed that is roughly about 157 solar masses. There is another independent events confirm are published by the Princeton group by the Syracuse group.

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00:15:37.950 --> 00:15:48.480

Karan Jani: Defined events in live or data which lygo does not consider you know the same significance level, but they exhibit black codes that are definitely about hundreds of our masters and the form after merging.

103

00:15:49.890 --> 00:15:56.430

Karan Jani: Now, I promise this last time. What does this mean for gravitational wave astronomy in future is that

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00:15:56.760 --> 00:16:05.250

Karan Jani: The next generation of instruments would get better at low frequencies, the lower the frequency, the higher the gravitational hard the binary black hole mass, we can see

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00:16:05.610 --> 00:16:15.240

Karan Jani: So this plot is one of those defining plots of gravitational wave astronomy, that the y axis is a redshift and log scale the x axis is it's the total mass and log scale.

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00:16:15.690 --> 00:16:24.120

Karan Jani: We can serve everything from Sub solar mass black holes to stellar black holes to intermediate mass black holes and supermassive black holes in the scale of next 15 years

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00:16:25.020 --> 00:16:33.630

Karan Jani: The different countries refer to the different epoch of gravitation. We have astronomy new instruments that were Tom the blue car is the space mission, Lisa.

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00:16:34.290 --> 00:16:43.830

Karan Jani: That is particularly sensitive to the higher size of intermediate mass black holes and the other cars on the left, refer to ground based detectors like Einstein telescope

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00:16:44.400 --> 00:16:57.480

Karan Jani: Which will see the lower total mass, but we will be able to serve practically every intermediate mass black hole in the observable universe in coming years. This was published as a cover of the nature of astronomy is trophy to read more about it.

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00:16:58.500 --> 00:17:02.160

Karan Jani: The last part is, then, do we see such signal in Lisa

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00:17:03.090 --> 00:17:11.610

Karan Jani: How yes we do see the same system and Lisa and that open something called a multi band astronomy, it is different than the multi messenger astronomy.

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00:17:11.940 --> 00:17:17.580

Karan Jani: Because in multi band you look the same way that a radio and x ray telescope can see the same source together.

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00:17:17.970 --> 00:17:23.190

Karan Jani: Here you have to gravitational detectors different frequency bands can see the same source together.

114

00:17:23.730 --> 00:17:35.820

Karan Jani: The plot on the left is a joint volume of the two different sensitivity band. So Lisa start seeing this very signal about four or 10 years before it's merger and why it is so crucial is that

115

00:17:36.510 --> 00:17:45.480

Karan Jani: We don't know if the system is is centric. We don't know what the spins of this exact same magnitudes of the side. But if we start seeing the system, eight years before.

116

00:17:45.990 --> 00:18:00.480

Karan Jani: Those morphology will be very strict how strongly impacted by this environmental parameters of the system we expect about eight to 36 sources that Lisa would see. So that's very promising science case that the detector offers

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00:18:01.980 --> 00:18:10.230

Karan Jani: In interest of time, I'm going to move on from the multi messenger part. So I just want to end on this note, which is an open question.

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00:18:11.190 --> 00:18:21.150

Karan Jani: That what then makes the signal. I'll say there are two things I'm two classes that I defined one is astrophysical that is standard astrophysics can make it. And the other is more exotic

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00:18:21.660 --> 00:18:30.780

Karan Jani: The standard astrophysics. Can this be stars can start not go to bed instability supernova and still mentors black holes so calculation about this.

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00:18:31.140 --> 00:18:37.920

Karan Jani: Professor lovin I'd done last year and we find that less than point 8% stars could make out what is black holes car.

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00:18:38.790 --> 00:18:50.970

Karan Jani: Candace Blackwell's be mergers of previous generation black holes. So can the first gravitational wave detection find another black hole and merge again. Yes. Maybe the probability is very low, for two reasons.

122

00:18:51.300 --> 00:19:02.310

Karan Jani: A the black holes, of course, have to be very dense environment to do so, but every time a merger happens, they get kicked away with a higher velocity. So you need something to to keep them glued in the globular cluster.

123

00:19:03.270 --> 00:19:14.610

Karan Jani: This can happen if the stars have been colliding in some sort of a runaway fashion in the young globular clusters, we have discussed that rate to refine about 8% of stars would end up doing this massive that is a channel.

124

00:19:16.050 --> 00:19:22.860

Karan Jani: Now there is another prominent channel which is forming this black hole in the AGM disk. So, this are not

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00:19:24.000 --> 00:19:33.900

Karan Jani: Per se, a standard stellar method I would have put it in exotic but now there is a growing community of people who are working on this model. So it has become very mainstream

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00:19:34.680 --> 00:19:43.020

Karan Jani: A strong claim is a possible electromagnetic counterpart, which has been associated with this very event. So that is something in future look out for.

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00:19:43.680 --> 00:19:53.130

Karan Jani: Can we roll out exotic things. Can this be a core collab supernova very unlikely because A, the morphology does not match and amplitude of signal that we have seen

128

00:19:53.520 --> 00:20:03.450

Karan Jani: Her for that to be a supernova, we would have also seen some other counterpart, like a neutrino signal. Can this be cosmic strings. We load into it with an extensive

129

00:20:04.230 --> 00:20:12.540

Karan Jani: Tests and more data does not favor cosmic strings at all over a binary black hole margin. Can this be beyond general relativity

130

00:20:13.140 --> 00:20:17.790

Karan Jani: Can this be not binary black holes that Einstein's theory predicts we

131

00:20:18.360 --> 00:20:25.950

Karan Jani: Subtracted we look at the lesson jewel in the signal. So you subtract what is the best matching Einstein's solution to the signal and look at what is left

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00:20:26.370 --> 00:20:40.860

Karan Jani: And we don't find any evidence for an engineer at the moment. Can this be strong gravitational lensing again unlikely the data does not

support for various arguments that we are present in the paper. The two things which we cannot rule out

133

00:20:42.300 --> 00:20:46.260

Karan Jani: Scan this the primordial black hole modules and very valid can be

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00:20:47.130 --> 00:20:57.990

Karan Jani: The spin is still fairly broad, you could think the primordial black holes may not be spinning as fast as a hierarchical Blackwood merger or there's ones that have come directly out of stars.

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00:20:58.350 --> 00:21:07.350

Karan Jani: So there is an evidence and this comes from fairly far away. If the merger happens at Richard one, that means the binary has happened, much, much earlier. So that exists.

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00:21:08.130 --> 00:21:15.750

Karan Jani: Can this be a highly central collision and we have not seen the central city because the signal is so short, very possible.

137

00:21:16.440 --> 00:21:25.800

Karan Jani: The reason we cannot do much about it, even if he were on new this scenario is that it's hard to model gravitational waves with generic centricity

138

00:21:26.760 --> 00:21:34.170

Karan Jani: So this is the open things. But what, in conclusion, I can say is that this mastering hundred 2000 solar mass

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00:21:35.070 --> 00:21:44.100

Karan Jani: Is perhaps one of the most excited exciting astrophysical sources in gravitational wave astronomy for the next 10 to 15 years because all detectors would be seeing the source.

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00:21:44.700 --> 00:21:59.970

Karan Jani: Unlike a binary neutron star, which only few on space doctors cannot see this one is pretty much common across gravitational wave experiments. So I hope you know we are able to it is check some of this models incoming times. Well, thank you so much for the patients.

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00:22:06.240 --> 00:22:07.620

Let me start my

142

00:22:09.180 --> 00:22:12.450
Ana Bonaca: Thank you so much for the great

143
00:22:13.350 --> 00:22:14.760
Ana Bonaca: Presentation and

144
00:22:14.850 --> 00:22:15.900
Karan Jani: Also very exciting.

145
00:22:15.930 --> 00:22:30.750
Ana Bonaca: Result need to start the questions and maybe you can still like use your slides. There's healthy. So for pro card and have a question about the the highly eccentric merger.

146
00:22:32.550 --> 00:22:43.410
Ana Bonaca: Yeah, she noted that there had been to recently several groups discussing that event is perhaps better match with an eccentric merger. Can you discuss what parts of the lack of data analysis, my kids to this.

147
00:22:48.840 --> 00:22:50.070
Oh, you're muted.

148
00:22:52.530 --> 00:23:07.440
Karan Jani: Okay. Can you hear me now. Yes, yes. So as you can see in the signal itself. This morphology is fairly tight. You know, we only see for wiggles. But if you see the black line which is a reconstruction of from a different search

149
00:23:09.570 --> 00:23:13.380
Karan Jani: There is something before the peak and after the peak that goes for multiple vehicles.

150
00:23:14.790 --> 00:23:29.760
Karan Jani: In that if we try to effect an eccentric merger. It may not saying it cannot but at this point the degeneracy is so high with this one signal that it is any claim would be very

151
00:23:31.110 --> 00:23:33.060
Karan Jani: Under quote unquote cabot's

152
00:23:34.260 --> 00:23:35.160
Karan Jani: For a central city.

153

00:23:37.230 --> 00:23:42.750

Ana Bonaca: Okay, and then the signal is like brilliant is this kind of outskirts of their kind of noisy.

154

00:23:44.400 --> 00:23:47.220

Ana Bonaca: So I had a maybe a related question of

155

00:23:48.330 --> 00:24:07.110

Ana Bonaca: Kind of teasing out the signal. So as much as we can out of, out of this. So it feels to me as a as a non expert that the contour lines in the in the mass plane are kind of wider than than what we're used to get like FOR, OTTER Lycos sources. So I was wondering, like is there.

156

00:24:08.490 --> 00:24:11.250

Ana Bonaca: What, how can we do better in providing

157

00:24:12.840 --> 00:24:16.140

Ana Bonaca: More precise mass estimates for these systems.

158

00:24:17.190 --> 00:24:27.480

Karan Jani: Do. So those are two things that here determine the mass. The mass here that I've reflected is the mass in the source frame. So when we see the gravitational waves. It has been read shifted

159

00:24:28.050 --> 00:24:47.430

Karan Jani: So we first have to fake Zoomer cosmology and then we find the redshift corresponding to the luminosity distance. And then we get the mass of the black holes in the source itself. So the error in distance usually ties in the errors. What we have in the mass itself. One of the things can

160

00:24:48.750 --> 00:24:53.010

Karan Jani: Be just thought the distance part. So, here again you can see that distance is fairly broad

161

00:24:53.580 --> 00:25:04.290

Karan Jani: We were able to break there is a degeneracy on the inclination of the binary and the far it is if it has had on sorry if its edge on weeks if the system as we much closer

162

00:25:04.680 --> 00:25:15.870

Karan Jani: Be used gravitational wave form that had what you call the beyond quadruple tones that allow radiation have access not perpendicular to the orbital plane but you know much more

163

00:25:16.770 --> 00:25:33.390

Karan Jani: In oil geometry because of those, we were able to break the degeneracy in the central city, at least for the two of the models, yet not much, you know, at this stage of the models that we have the level of securities on the expectation is that if you see a lot more of this.

164

00:25:34.470 --> 00:25:45.630

Karan Jani: I did some of them would be at a higher signal to noise ratio on this one has a signal to noise of 115 if you compare with the first detection, which had a very tight masses that was about 24 signal to noise.

165

00:25:48.180 --> 00:25:49.200

But make a difference.

166

00:25:51.000 --> 00:25:51.390

Ana Bonaca: Guess.

167

00:25:51.660 --> 00:26:11.370

Ana Bonaca: Shifting a little bit. Our topic of discussion into the kind of the origin of basically has a has a question of how likely would you say it is that this black hole is the result of a Prius merger. And what would that tell us about the possible hierarchy of merging black holes.

168

00:26:13.620 --> 00:26:24.720

Karan Jani: So we did compute the probability that can it be a second generation merger of some sort, you know, and the influences, we would get is in the spin itself.

169

00:26:25.080 --> 00:26:32.610

Karan Jani: Because if it's a second generation and the spin of the black hole has to be greater than point seven close to 70% of the theoretical limit.

170

00:26:34.920 --> 00:26:47.400

Karan Jani: What we in this have coming up study. I'm just going to flag it here. We are looked at all the heavy black holes that have been seen in gravitational waves. So far, not just this event, but the other ones too.

171

00:26:47.850 --> 00:26:58.740

Karan Jani: And we try to make a fit with a spin parameter which is this emergent spin. It's a some of the two black hole spins combined and on the x axis you find the mass of the primary black hole.

172

00:27:00.360 --> 00:27:06.240

Karan Jani: We can fit it, the data is supposed this kind of effect, where are you this, you start with

173

00:27:06.720 --> 00:27:18.060

Karan Jani: At least point seven spend to begin with, as you increase the total mass. So once you are in the spare instability mass limit the black hole spin seems to be slightly higher than the lighter black holes that we have seen

174

00:27:19.050 --> 00:27:28.320

Karan Jani: This is you can see the distribution is fairly broad spins are very tough to constrain from the system, but this is where we need something like a lease on mission, essentially, to have

175

00:27:32.550 --> 00:27:32.850

That

176

00:27:34.650 --> 00:27:35.700

Ana Bonaca: Working had

177

00:27:37.500 --> 00:27:50.820

Ana Bonaca: Kind of follow up question on the on the Lisa treads saying so my, that's my goodness lab. I'm assuming that Elisa section will constrain the eccentricity. Can you talk about what a Multi Frequency detection would constraint for us.

178

00:27:52.260 --> 00:28:00.210

Karan Jani: So the two things that Lisa would be able to constrain you know one some more directly, we would have a hint on the merger time

179

00:28:00.960 --> 00:28:16.680

Karan Jani: From the so so zoom. Let's say that there's black holes have form in an agent disk. So that is gas and relation around this Black Codes, which would influence, it's a it's evolution versus if it is in a vacuum. So in principle you could place this black hole, much closer

180

00:28:17.880 --> 00:28:21.450

Karan Jani: Than you would have done in an in an isolated environment.

181

00:28:22.500 --> 00:28:33.090

Karan Jani: This signature is reflected in Lisa because the gravitational strain would follow different slow your separation is different. So the gravitational wave emitted has a different slow

182

00:28:33.810 --> 00:28:44.400

Karan Jani: We would be able to test this in Lisa right about we can't really do much in live band because by the time the system has become almost circular almost, you know, vacuum around it.

183

00:28:45.570 --> 00:28:55.020

Karan Jani: But yeah, so this is just one lot of merger time versus separation for different channels and the central city would also be somewhere here, and would have a very distinct part

184

00:28:57.060 --> 00:28:57.690

So,

185

00:28:59.220 --> 00:29:01.440

Ana Bonaca: Maybe just as a as a close

186

00:29:02.520 --> 00:29:10.260

Ana Bonaca: Close up here to you. What resources do you think we should be starting to get ready to be able to follow up.

187

00:29:11.280 --> 00:29:13.710

Ana Bonaca: These possible Lisa detections.

188

00:29:14.910 --> 00:29:22.470

Karan Jani: So the most important challenge we have right now and Lisa detection is to get the waveforms on that we would need to study the system.

189

00:29:23.640 --> 00:29:31.920

Karan Jani: We recently published another study where if you use the current simulations we have and the level of signal to noise. You've seen the size about thousand

190

00:29:32.490 --> 00:29:44.040

Karan Jani: Minimum hundred 2000. So what happens is your numerical errors of this very simulation of solving it is as good as any of the Non GMO effects that we are trying to find

191

00:29:45.090 --> 00:29:51.780

Karan Jani: And just not non GMO, even if the system is processing or so those effect gets confused, just with a numerical noise now.

192

00:29:52.740 --> 00:30:06.630

Karan Jani: So one big in study. Perhaps you know that needs to be done over the time I THE COMMUNITY IS GET AWAY FROM gravitational waves signal Models that work in Lisa and because we are still 15 years from that can take a little break.

193

00:30:08.910 --> 00:30:12.990

Karan Jani: But so this is something very urgent on in terms of development.

194

00:30:14.130 --> 00:30:15.390

Ana Bonaca: Okay, awesome. Well,

195

00:30:16.560 --> 00:30:34.200

Ana Bonaca: Thank you so much for this exciting updates will be looking forward to how the story develops. So that also have the the paper in prep is is for nature submission. So yeah, hope to be able to invite you again soon to tell us more about it.

196

00:30:34.770 --> 00:30:35.610

Karan Jani: Thank you so much.

197

00:30:36.390 --> 00:30:46.860

Morgan Elowe MacLeod: Thank you. Yeah, thank you for really interesting talk. So allow me to introduce our second speaker who, as a member of the CFA

198

00:30:47.730 --> 00:31:03.540

Morgan Elowe MacLeod: Needs sort of very little introduction, but Catherine Zucker will tell us about some of her recent work Catherine is a postdoc now at the Center for Astrophysics previously. She received her PhD this past May, May 2020 from Harper.

199

00:31:04.890 --> 00:31:10.920

Morgan Elowe MacLeod: Where during her thesis work. She was advised by professors Alyssa Goodman and Doug finkbeiner

200

00:31:12.420 --> 00:31:24.720

Morgan Elowe MacLeod: She is sort of a world expert on mapping the much more local universe are part of the galaxy in three dimensions and

201

00:31:25.410 --> 00:31:42.960

Morgan Elowe MacLeod: Pulling in all of the constraints we can to better understand our place in the galaxy. During her time as a graduate student. She received and was supported by a number of fellowships and including by the National Science Foundation graduate research fellowship

202

00:31:44.640 --> 00:31:50.940

Morgan Elowe MacLeod: But without further ado, Catherine. We're excited to hear what you've been up to recently. Thank you.

203

00:31:51.480 --> 00:31:55.650

catherinezucker: Thank you. Morgan and thank you for inviting me to be here and we just share my screen really quick.

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00:32:01.800 --> 00:32:06.570

Morgan Elowe MacLeod: And I'll play. I'll play that bad Bell when you have about five minutes left.

205

00:32:06.960 --> 00:32:08.100

catherinezucker: Okay. Sounds good.

206

00:32:25.980 --> 00:32:26.430

catherinezucker: See my screen.

207

00:32:28.380 --> 00:32:39.480

catherinezucker: Yep. Okay. Okay. So thanks again on and Morgan, for inviting me to be here. I'm very excited. I'll bite virtually and today I'm going to be talking about 3D mapping and the age of Gaia.

208

00:32:40.050 --> 00:32:46.860

catherinezucker: And so I just like to give many thanks to my money wonderful collaborators. You can see listed here without which this work would not be possible.

209

00:32:48.390 --> 00:32:58.170

catherinezucker: Without further ado, 3D mapping in the age of Gaia so 3D mapping and the age of Gaia involves combining Gaia data with large for the metric surveys

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00:32:58.560 --> 00:33:06.240

catherinezucker: And new computational and statistical techniques to map out the 3D distribution of interstellar deaths in our Milky Way galaxy.

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00:33:06.840 --> 00:33:15.810

catherinezucker: And so this could take up many, many hours, but I just want to preview for this talk to have the main results that have been obtained using 3D mapping and the guy era.

212

00:33:16.230 --> 00:33:22.350

catherinezucker: And so one of them is going to be on killer parsecs scales and then we're going to zoom down into parsecs scales in our neighborhood.

213

00:33:23.010 --> 00:33:32.760

catherinezucker: So I'm parsecs on Kyla parsecs scales. I'm going to show new results on the 3D spatial distribution of nearby star mean regions obtain with 3D mapping

214

00:33:33.150 --> 00:33:37.020

catherinezucker: And particularly, I'm going to present the discovery of the structure that you see right here and read

215

00:33:37.350 --> 00:33:45.930

catherinezucker: Which is called the Radcliffe wave and each red blob is a star from a region, whose distance has been actually accurately measured and Gaia.

216

00:33:46.560 --> 00:33:51.540

catherinezucker: And so this structure was not known before the rise of Gaia and in particular is very interesting.

217

00:33:51.870 --> 00:33:58.650

catherinezucker: Because it's incredibly linear when you see it from top down, but it undulates with respect to the galactic plane when you see it from the side.

218

00:33:59.070 --> 00:34:03.630

catherinezucker: And so we think that this structure is actually a dense spine of the local arm of our galaxy.

219

00:34:04.500 --> 00:34:12.420

catherinezucker: And so I'll start with the Radcliffe wave and then by the end we're going to actually zoom down into individual star forming regions inside the Radcliffe wave

220

00:34:12.630 --> 00:34:18.390

catherinezucker: So resolving the structure of individual molecular clouds that are forming and this much larger swath of the square alarm.

221

00:34:18.900 --> 00:34:25.170

catherinezucker: And so for people who study star for any reason you might think that this little cutout that I show here is actually a simulation.

222

00:34:25.500 --> 00:34:32.670

catherinezucker: But it's not. It's actually a 3D view of the dust and a local molecular cloud the Perseids molecular cloud at one sec.

223

00:34:33.210 --> 00:34:42.390

catherinezucker: And so the reason why I think this is so exciting and particular for the theory and computation colloquium is because, really, for the first time, we're able to resolve.

224

00:34:42.750 --> 00:34:54.090

catherinezucker: The 3D structure of our galaxy on scales comparable to numerical simulations at large dynamic range. So from swath of spiral arms all the way down to individual star three regions and assigned molecular clouds.

225

00:34:54.450 --> 00:35:03.480

catherinezucker: And so you can even begin to test from both the theory and an observational perspective how things like electrodynamic feller feedback and then it feels the gravity of the gas.

226

00:35:03.840 --> 00:35:09.540

catherinezucker: How that shapes star formation and molecular clouds and how that shapes the star from the history of galaxies like our Milky Way.

227

00:35:10.830 --> 00:35:17.820

catherinezucker: So before I get into the meat of the results. I just want to show briefly how fitness mapping actually works and how it got a huge distance resolution boost from Gaia.

228

00:35:18.780 --> 00:35:28.200

catherinezucker: Said that we have a star and the observed the star in our galaxy. So we have broadband for telemetry for billions of stars in our galaxy. So we have

229

00:35:28.650 --> 00:35:38.070

catherinezucker: Knowledge of the colors that optical infrared wavelengths from surveys like pan-starrs and TMS. And if there was no dots between us and the star that star would appear yellow tasks.

230

00:35:38.700 --> 00:35:47.130

catherinezucker: And it's intrinsically yellow. However, we know that if there is a dark cloud between us and the star. The colors of that star will be readings.

231

00:35:47.820 --> 00:35:57.900

catherinezucker: And so you can see that very clearly in something like this nearby dark cloud be 68 were on the outskirts of the cloud, you have this reading effects and then that's not true for stars.

232

00:35:58.230 --> 00:36:06.210

catherinezucker: Not along this dark was line of sight that are in the background. And so in reality we have billions of stars scattered throughout these dust clouds in our galaxy in 3D.

233

00:36:06.780 --> 00:36:19.650

catherinezucker: And how read in those stars will become will depend on whether they lie in front or behind the dust cloud. So stars behind the dust cloud will appear more readings and stars in front. And so what you can essentially do is bracket dark clouds between these two types of stellar

234

00:36:19.650 --> 00:36:20.580

Alexandra Shelest: Populations.

235

00:36:21.360 --> 00:36:30.060

catherinezucker: So reality. This is much more complicated. Of course, as everything is so these stars have different intrinsic types, you have to model the type of the star. So dwarfs and giants were very different colors.

236

00:36:30.390 --> 00:36:34.980

catherinezucker: You have to model the distance of the star any of the model, the amount of dust between you and each star.

237

00:36:35.670 --> 00:36:46.290

catherinezucker: But if you can do all that, and with new computational statistical techniques you can infer the clouds distance. And that's the 3D distribution of molecular clouds from the dust effects on stars.

238

00:36:47.220 --> 00:36:56.970

catherinezucker: And so you can do this entirely without Gaia, but when you actually add an independent constraints on the distances to stars from Gaia, you get a huge distance resolution boost.

239

00:36:57.240 --> 00:37:03.870

catherinezucker: And so you can resolve these clouds in detail. THAT WAS IN DETAIL, DETAIL, DETAIL do these clouds. It was never possible in the pre guy era.

240

00:37:05.310 --> 00:37:15.480

catherinezucker: So this is actually look like in practice. So sort of this in France looks like. So this is essentially showing you what the dust how the desk varies is a function of distance along three sightlines in our galaxy.

241

00:37:16.530 --> 00:37:24.510

catherinezucker: Through local molecular cause the through famous star for me, regions and so on the Y axis, this is the integrated amount of deaths a long line of sight so integrated extinction.

242

00:37:25.410 --> 00:37:34.650

catherinezucker: And on the x axis is the distance or distance modulus and then each of these red crosses our marketing position that distance an extinction individual stars along some sideline.

243

00:37:35.250 --> 00:37:39.900

catherinezucker: And so you'll see in the foreground that there's this directions on red and foreground population nearby.

244

00:37:40.320 --> 00:37:49.950

catherinezucker: And then there is this red end population of stars at further distances and so you know that the cloud has to live between these two populations in order to produce the colors that we observed for the stars.

245

00:37:50.370 --> 00:37:56.490

catherinezucker: And this is actually the pre guy version of these plots. But once you actually add an independent constraints and the distances from Gaia.

246

00:37:56.760 --> 00:38:02.760

catherinezucker: You get a much darker view of the distances and you're going from uncertainties on distances of like 25 to 30%

247

00:38:03.120 --> 00:38:12.600

catherinezucker: And distance uncertainty is down to about 5% and so you're improving on the assessments by a factor of five, which allows you to reveal the existence of new structures in the galaxy like the Radcliffe wave

248

00:38:13.560 --> 00:38:21.720

catherinezucker: But don't take my word for it. So we're going to actually compare our distances obtained via 3D mapping with the gold standard for star forming regions in our field.

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00:38:22.140 --> 00:38:31.680

catherinezucker: And thankfully, the people who have produced these gold standard distances, I think, are both on this call Mark Read and Tom Dame who have led the, the battle survey here at the Center for Astrophysics

250

00:38:32.070 --> 00:38:38.700

catherinezucker: And so what we've done is we've compared sorts with the gold standard distances to start from the regions from vessel. So maser

251

00:38:39.180 --> 00:38:45.780

catherinezucker: These are parallax measurements towards Hi star from and regions with our desk space distances in the era of Gaia and regions of overlap.

252

00:38:46.710 --> 00:38:50.310

catherinezucker: So you've probably seen a plot that looks like this. This is the major view of our galaxy.

253

00:38:50.730 --> 00:39:02.250

catherinezucker: So each of these different colored points are showing you. Hi, Matt Starfleet regions along different arms. So this is the galactic center. This is the sun. And so we're going to essentially compare with all the majors in our neighborhood and cyan along the local arm.

254

00:39:03.780 --> 00:39:12.780

catherinezucker: And we find really good agreements so we agree with the gold standard of segments within 10% and we find no systematic offset out to 2.5 kilo parsecs.

255

00:39:13.200 --> 00:39:20.010

catherinezucker: Which is great because even though these are the gold standard and they've informed much of our view of galactic structure over the past 10 years

256

00:39:20.400 --> 00:39:32.370

catherinezucker: The, the great thing about 50 desk mapping is that can be used anywhere where you have dust and measurable stellar properties you can essentially fill in the gap with the with the major distances using 3D distances.

257

00:39:34.620 --> 00:39:40.890

catherinezucker: And so this is what that looks like. So essentially we target all of the famous nearby star for many regions within 2.5 kilowatts x

258

00:39:41.310 --> 00:39:45.510

catherinezucker: And this is a top down view of the global distribution of those nearby star coming regions.

259

00:39:45.960 --> 00:39:53.220

catherinezucker: So the, the background gray scale, the sun's here in the background gray scale shows the video distribution of all the deaths in the galaxy.

260

00:39:53.580 --> 00:39:58.170

catherinezucker: Obtained by former Harvard Harvard PhD student grad greens. You can see it on the right hand side.

261

00:39:58.830 --> 00:40:06.600

catherinezucker: And then the blue points show just the most accurate distances to the, the regions that are forming stars. So the blue points show the molecular clouds.

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00:40:06.960 --> 00:40:15.060

catherinezucker: And so the two techniques are very complimentary. But essentially, we sacrifice using star from the region distances we sacrifice angular resolution for distance resolution.

263

00:40:15.330 --> 00:40:19.200

catherinezucker: And so we're able to constrain the global distribution of star community just a very high precision.

264

00:40:19.710 --> 00:40:27.090

catherinezucker: And so we see a lot of structure in this diagram. So people who are used to say in the galaxy might note that this is the Sagittarius crime arm over here, a section of it.

265

00:40:27.390 --> 00:40:30.480

catherinezucker: This is a very famous star formation called this cosine Association.

266

00:40:30.990 --> 00:40:42.090

catherinezucker: But what interested us the most is that there's this very peculiar linear, linear chain of star for me regions that extends about 2.7 kilo parsecs is very straight. So when you see it, top down.

267

00:40:42.450 --> 00:40:48.600

catherinezucker: But it's even more peculiar when you actually look at it from the side. And so this is this the Radcliffe wave structure. As I mentioned at the very beginning.

268

00:40:49.110 --> 00:40:58.620

catherinezucker: So it's named the Radcliffe wave, because the the lead authors about this was a Rockefeller here a few years ago and he was frequent frequently was at the Center for Astrophysics and so we collaborated

269

00:40:58.950 --> 00:41:01.440

catherinezucker: On this work with many others, and it's now in nature.

270

00:41:02.040 --> 00:41:14.100

catherinezucker: And so essentially what we find is that all of the most famous nearby star free and region. So regions like a Ryan or sing us x, they're actually connected into one long linear filaments with an aspect ratio about 22 one

271

00:41:14.550 --> 00:41:21.150

catherinezucker: Very crazy. But if you actually look at it from the side. So the side being actually look at how this structure undulates expects the galactic plane.

272

00:41:21.600 --> 00:41:26.130

catherinezucker: You find that all the famous star for me regions are actually take the form of a dance sine wave.

273

00:41:26.550 --> 00:41:30.660

catherinezucker: With an amplitude of about 160 parsecs in a period of about two color parsecs.

274

00:41:30.990 --> 00:41:39.990

catherinezucker: And so we've never seen a structure exactly like this in our galaxy and a sort of the largest go here and structure and we think actually a section of this fire alarm that has ever been mapped high resolution.

275

00:41:40.890 --> 00:41:56.610

catherinezucker: That's actually want to show you exactly how this looks like with respect to the existing models for the spiral for the local aren't based on meters. So I'm going to give this like 10 seconds to load. And you'll get to see a very cool interactive figure of our neighborhood.

276

00:41:58.740 --> 00:42:01.800

catherinezucker: And so specifically what we're finding and also in a second.

277

00:42:02.820 --> 00:42:16.680

catherinezucker: Is that we think this Radcliffe wave actually is a dense, find a local arm nearby. So the 3D view of what I just showed you. This is the top down view. And then this is the the side view and I want to overlay where we think the majors live with respect to this feature.

278

00:42:17.730 --> 00:42:24.900

catherinezucker: So you sing in dark blue here so dark blue. Those are the, the major position. So those are high mass star from the regions from vessel.

279

00:42:25.320 --> 00:42:33.300

catherinezucker: And then this blue curve right here. That is the the sort of the global fit to the local arm constrained by majors way outside this diagram.

280

00:42:33.870 --> 00:42:43.410

catherinezucker: But what we're finding is that by mapping, not just hi my star students like with majors, but also mapping lower master coming regions that we're essentially revealing this very dense spine of the local arm.

281

00:42:43.830 --> 00:42:50.340

catherinezucker: And that's at least on local scales and then the new in the future nearest few killer parsecs.

282

00:42:50.820 --> 00:43:01.800

catherinezucker: We think that the arm is actually super linear for top down and waiting from the side. And so that's actually also been observed in in nearby galaxies. And so we think that we're essentially revealing this arm at very high spatial resolution.

283

00:43:04.410 --> 00:43:06.960

catherinezucker: And so there's a few implications here that I just want to go over

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00:43:10.140 --> 00:43:15.480

catherinezucker: So the first that already touched upon is that the local arm we think is not shaped as we thought it was locally.

285

00:43:16.110 --> 00:43:24.870

catherinezucker: And then it straight from top down and we become the sign so on on large scales, it might look like a log spiral and the plan of the galaxy, but on small scales it very much does not

286

00:43:25.830 --> 00:43:32.460

catherinezucker: The waves origin is unknown, but it has serious implications for understanding of the star formation history of galaxies like the Milky Way.

287

00:43:32.910 --> 00:43:42.930

catherinezucker: So there's a couple possible explanations. So one of them is that there's a could be a collision. So something like the size of this Sagittarius Dwarf galaxy bit of hit Milky Way and cause the

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00:43:43.350 --> 00:43:50.820

catherinezucker: Just undulates but there have also been studies of nearby acts like external edge on galaxies, where they can

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00:43:51.240 --> 00:43:57.270

catherinezucker: Explain ripples and other discs based on global gravitational stability and stability is without the need for a butterbur

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00:43:57.930 --> 00:44:05.610

catherinezucker: And so what we really need to differentiate between these two scenarios is 3D stellar kinematics. So pretty information on the young stars in the Radcliffe wave

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00:44:05.940 --> 00:44:13.860

catherinezucker: And so we have a really excellent. Are you student price student actually he's now working with us this semester. His name's Alan too. So hopefully we'll get to the bottom of the student

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00:44:14.760 --> 00:44:21.780

catherinezucker: And then the final implication is that we find that the stars me regions that were previously thought to be isolated are actually very much not so

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00:44:22.080 --> 00:44:30.900

catherinezucker: And they're connected by these lower density tendrils of gas. And so it really forces you to rethink our understanding of local star formation and in a larger galactic context.

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00:44:32.580 --> 00:44:40.200

catherinezucker: And so we have the right foot wave. And we've characterized the structure of the inner so I mean I'm a very large scales. So on several Philip carsick scales.

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00:44:40.530 --> 00:44:53.250

catherinezucker: And so now for the last few minutes of the talk. I want to actually zoom down into individual molecular clouds inside the Radcliffe wave and understand what's happening on on parsecs skills in individual clouds.

296

00:44:54.030 --> 00:45:05.010

catherinezucker: And so this is a view again of like the global view of the dust. So the background gray skills from green adult doesn't 19 years the desk map and then the red is the rack the flavor and the white is the is the model for the Radcliffe wave

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00:45:05.880 --> 00:45:13.680

catherinezucker: And so what we're gonna do is we're going to pull in complimentary results may vary new feed so map from like a glass line. And so in 2020

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00:45:14.100 --> 00:45:21.630

catherinezucker: And so essentially what they've done is they've looked at the dust just in the nearest 370 parsecs from the sun.

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00:45:22.080 --> 00:45:30.720

catherinezucker: And so this large scale desk map and a smaller scale does not, they actually use very similar like fundamental unit of inference. So they're both based on this.

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00:45:31.650 --> 00:45:41.280

catherinezucker: Estimates of distance and extension for individual stars, but essentially they're sacrificing the amount of volume, they can probe in the galaxy in order to get increased spatial resolution.

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00:45:41.640 --> 00:45:49.080

catherinezucker: And so they've produced this new map at 1% spatial resolution for the nearest they're going to 70 parsecs using a Gaussian process based technique.

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00:45:50.040 --> 00:45:58.050

catherinezucker: And so what we're gonna do is we're going to zoom in one time further and we're going to actually look at individual clouds. For me, then the Radcliffe wave in 3D.

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00:45:58.680 --> 00:46:07.230

catherinezucker: And we're going to do a few things we're going to actually characterize for the first time the 30 specialty apologies of molecular clouds nearby.

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00:46:07.740 --> 00:46:15.060

catherinezucker: But we're also actually going to measure their video density profiles in order to sort sort of get at the the physics that shaping these clouds on parsecs skills.

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00:46:22.620 --> 00:46:27.450

catherinezucker: So it's this prestigious prestigious molecular cloud again and I'll show you what Perseus looks like on the planet of sky in a little bit.

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00:46:27.930 --> 00:46:38.160

catherinezucker: But there's a few steps that we take to analyze the topology. So first, what we do is where essentially taking tools that were originally designed to study clouds in 2D on the plane in the sky.

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00:46:38.610 --> 00:46:48.120

catherinezucker: Or in America simulations, or in position position, velocity view. So the interstellar medium. So, based on spectral line mapping where the third axis is knots

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00:46:48.690 --> 00:46:56.370

catherinezucker: Distance but velocity and sort of are we working them to actually be able to be applied to observations of the 30 spatial distribution of dust, for the first time.

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00:46:56.850 --> 00:47:03.510

catherinezucker: And so we're applying this new code call not new code, but a revamped version of an old code called fill finder, which is actually

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00:47:03.990 --> 00:47:08.220

catherinezucker: Produced by incoming SMS fellow Eric costs. So really excited to have him here.

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00:47:08.670 --> 00:47:16.380

catherinezucker: For the coming years. But essentially, what we're doing is we're essentially extracting the topological skeletons of all of the nearby clouds at one part of the resolution.

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00:47:17.310 --> 00:47:24.060

catherinezucker: You can see that's what the sky looks like for this cloud. And it's actually a colored by distance from the Sun and I'll show you that in a second and an interactive view.

313

00:47:24.900 --> 00:47:33.240

catherinezucker: But essentially what we've measured for the first time in 3D is the radial density profiles of the clouds nearby.

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00:47:33.660 --> 00:47:38.640

catherinezucker: So essentially we're measuring how the gas density drops off the function of distance from the spine.

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00:47:39.300 --> 00:47:46.470

catherinezucker: Which can tell you something about the thicknesses of clouds, but also about the various forces external pressure gravity, so on and so forth that are shaping that's apologies.

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00:47:47.220 --> 00:47:52.440

catherinezucker: So this work is still in its very early stages with something that is pretty exciting that I think popped out right away.

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00:47:52.860 --> 00:48:04.320

catherinezucker: Is that if you actually model the profiles of these clouds. They actually favor having two components. They actually favor having like a sort of a denser in or envelope with a narrower amplitude. So like an inner envelope.

318

00:48:04.890 --> 00:48:11.430

catherinezucker: And then they also favor actually having a much broader lower density outer envelope.

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00:48:11.850 --> 00:48:14.490

catherinezucker: And so they favor, all of them. Favorite having this type of profile.

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00:48:14.790 --> 00:48:24.180

catherinezucker: And it's potentially very exciting because it could be in that we're actually tracing two different phases associated with the the desktop so like a lower atomic phase we know all these clouds have atomic envelopes.

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00:48:24.480 --> 00:48:32.340

catherinezucker: And then potentially like a more diffuse molecular face towards the entire regions. And so this is true, and we can verify this. We

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00:48:32.340 --> 00:48:36.420

catherinezucker: Could say that we're actually tracing the h1, h2 transition potentially

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00:48:36.660 --> 00:48:37.920

catherinezucker: In local molecular clouds.

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00:48:39.510 --> 00:48:49.200

catherinezucker: So I just want to show you this star from the region, a little bit more detail. This is again Perseus and so all the people who attend star formation journal club and this talk will know about Perseus but just as a recap.

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00:48:49.590 --> 00:48:54.960

catherinezucker: Perseus. It's one of the most famous nearby star coming regions. So you can see Parsees here in 3D.

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00:48:55.470 --> 00:49:05.280

catherinezucker: On this is again the 3D distribution of deaths and XYZ space for Perseus and I've shown you overlay the the skeletal topology, the spine that we've computed for this cloud.

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00:49:05.850 --> 00:49:15.000

catherinezucker: And it's colored by distance. And then we've projected back that back on the plane in the sky and you can see essentially how Perseus looks before and to eat dust.

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00:49:15.300 --> 00:49:22.860

catherinezucker: So the background gray scale that shows you sort of the common way that we analyze molecular clouds nearby using to the destination or just extinction.

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00:49:23.460 --> 00:49:32.310

catherinezucker: But now we're actually able to say to very high precision exactly where your clump of gas or your poor your wife. So your protoplanetary desk lives in a molecular cloud.

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00:49:32.700 --> 00:49:40.470

catherinezucker: And how much staff that spans along the line of sight for the first time and and protected. I just want to show that to policies that we've analyzed for the clouds.

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00:49:41.340 --> 00:49:46.500

catherinezucker: So this is the inner topology, which I think is like the inner envelope of the clouds and this is the outer envelope.

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00:49:46.950 --> 00:49:52.920

catherinezucker: And so we now know exactly how those project back onto the plane of the sky and we can actually compare them, and knit together. Other information.

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00:49:53.820 --> 00:50:09.750

catherinezucker: From other tracers like SEO or H1 and or two deaths to understand for the first time in 3D and 2D the the masses and the densities and the length and the thickness of clouds, which is really exciting. If you've been studying these local regions for for many, many years.

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00:50:11.220 --> 00:50:19.200

catherinezucker: And so we've done this sort of analysis for many of the most famous nearby clouds. We've under for 10 of them Me show you right here. So we found their skeletons apologies.

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00:50:20.220 --> 00:50:23.640

catherinezucker: I'm going to be also measured their radio dusty profiles for all of these calls as well.

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00:50:24.390 --> 00:50:38.820

catherinezucker: And a few things pop out. So the first thing is that all of them also prefer this inner and outer envelope. So again, potentially indicative of like a atomic envelope and I like a diffuse molecular inner envelope, but the implications for that extend beyond just the video density profiles.

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00:50:40.110 --> 00:50:46.320

catherinezucker: So to wrap up, I just want to summarize what we've been doing a small scales. So we can actually characterize the specialty apologies of the clouds.

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00:50:46.830 --> 00:50:50.850

catherinezucker: Within 400 parsecs at one parsecs resolution for the first time.

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00:50:51.420 --> 00:50:56.820

catherinezucker: And we've known that molecular clouds of film memory at very high densities for quite a while for about 10 years from parcel.

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00:50:57.180 --> 00:51:06.150

catherinezucker: We're finding that even at lower density is that the clouds really are preferred to be elementary even at densities less than 100 particles per cubic centimeter, which was not known before.

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00:51:06.750 --> 00:51:14.010

catherinezucker: And then the other thing is that we see that these density profiles favor the existence of these inner and outer envelopes, which

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00:51:14.340 --> 00:51:21.930

catherinezucker: We think will be rolled out being an artifact of the modeling and we think it is actually real, but whether it is a phase transition is too soon to tell

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00:51:22.470 --> 00:51:26.790

catherinezucker: But either way, we provide at the first measurements of the thickness of clouds in 3D.

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00:51:27.540 --> 00:51:34.650

catherinezucker: We've provided measurements of the outer envelope. So the clouds. We've also applied. Couple other different models to describe the physics of what's happening here.

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00:51:35.100 --> 00:51:41.190

catherinezucker: And regarding there's an average ratio about 321 and so we have to essentially evoke some theory. So explain why that would be true.

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00:51:41.730 --> 00:51:48.180

catherinezucker: So we're going to look. So there's some some future analytic models in the coming months and also compare it in miracles simulations to try to explain this.

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00:51:48.870 --> 00:51:57.180

catherinezucker: But I just want to conclude by saying that I think it's a very exciting time to be studying the 3D structure of the interstellar medium, either in

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00:51:57.840 --> 00:52:00.270

catherinezucker: From an observational perspective, or from from theory.

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00:52:00.570 --> 00:52:09.690

catherinezucker: Because really this is only the start and as you add in more and better guy and data and you add in deeper photo metric surveys, you can get higher and higher resolution views of the interstellar medium.

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00:52:10.020 --> 00:52:15.300

catherinezucker: And as you bring an other tracers of the gas so spectral line cubes and young stars, you can really begin to trace

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00:52:15.660 --> 00:52:24.150

catherinezucker: And understand how stark mission is happening from scales of pillow parsecs. All the way down to our sub regions inside one for clouds. So with that, I just want to thank you for your time.

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00:52:25.290 --> 00:52:25.530

Thanks.

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00:52:29.490 --> 00:52:29.790

Ana Bonaca: Thank you.

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00:52:32.340 --> 00:52:33.480

Ana Bonaca: For the great doc.

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00:52:34.950 --> 00:52:35.790

Ana Bonaca: I guess I will

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00:52:36.840 --> 00:52:37.320

Ana Bonaca: Take

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00:52:39.090 --> 00:52:47.430

Ana Bonaca: A host privileges, the first question, just wondering, my everyone to please post your questions I had during the zoom chat or on the Slack channel.

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00:52:48.690 --> 00:53:01.410

Ana Bonaca: I wanted to kind of follow up on exactly what you were saying that that future gather data will provide improvements. My question is exactly how much of an improvement. Can we expect is especially now with

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00:53:02.550 --> 00:53:07.140

Ana Bonaca: The early. The early history being announced to

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00:53:08.250 --> 00:53:11.820

Ana Bonaca: To come out on December terms. So it's kind of very eminent

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00:53:13.110 --> 00:53:18.240

catherinezucker: Yeah, so, so the the incoming got a release from Gaia, so it'll definitely improve the

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00:53:19.470 --> 00:53:26.790

catherinezucker: The parallax mission I think will improve like by a few 10s of percent I think. But I think the bigger games is in the proper emotions will get better.

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00:53:27.180 --> 00:53:30.900

catherinezucker: And then in the upcoming release from Gaia it or three

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00:53:31.500 --> 00:53:42.030

catherinezucker: Will actually get lots more radio velocities which is not necessarily important for mapping the 3D distribution of dust, but it's really important for understanding the kinematics of the young stars and these regions.

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00:53:42.720 --> 00:53:49.500

catherinezucker: So essentially what happens is that we know that the Radcliffe wave has is gashes right and so there's young stars and the Radcliffe wave

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00:53:49.830 --> 00:53:53.580

catherinezucker: And we know that the young star should inherit the motion of their parental cloud.

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00:53:54.000 --> 00:53:59.730

catherinezucker: And so the more rate of velocity measurements that you have for the young stars, the better you can actually characterize the motion of

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00:54:00.180 --> 00:54:04.590

catherinezucker: Features like the rack with wave in 3D. And so we think will be able to better characterize actually

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00:54:04.980 --> 00:54:16.110

catherinezucker: Not just the distribution of the desk, but actually the the kinematics of the gas and the rights of way, which will be important

for constraining its origin. And so that's something that's Alan Alan are our new student is planning to work on when that comes out.

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00:54:17.400 --> 00:54:27.720

Ana Bonaca: Awesome. We have a question sort of along those lines gentleman asked how does the elementary geometry relates to the magnetic field direction.

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00:54:29.250 --> 00:54:37.350

catherinezucker: That is a great question and one something that I actually haven't looked into. But there's, there's the possibility to do this a lot better in the future.

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00:54:38.730 --> 00:54:44.790

catherinezucker: So, so we do notes. That's so not necessarily in Perseus but we have looked at

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00:54:46.020 --> 00:54:56.790

catherinezucker: Like starlight polarization and also magnetic fields is traced by plonk and destination and we're finding in particular that some of these larger structures and Taylor structures that are bubble like

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00:54:57.450 --> 00:55:07.290

catherinezucker: That you see the magnetic fields are threading the the shells of these clouds in 3D. But one of the things that I didn't actually get the touch upon but will be super significant in the future.

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00:55:07.920 --> 00:55:11.730

catherinezucker: Is there have been recent results by one of our collaborators named Susan Clark.

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00:55:12.210 --> 00:55:21.300

catherinezucker: Who's who many of you may know, is actually mapped the 30 structure than it fields in ppb space. So in position to this and velocity space using H1.

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00:55:21.810 --> 00:55:27.750

catherinezucker: And so in the future we should be able to actually knit together information on the H1 structure.

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00:55:28.200 --> 00:55:37.650

catherinezucker: Of the magnetic fields as a function of velocity with the 3D desks and so in the next year or two, hopefully will actually have a much better answer to that question and actually be able to map, not just the dust in 3D.

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00:55:38.190 --> 00:55:45.840

catherinezucker: But also the metadata fields and, in which case I can give you a much more thorough answer them. But we're still in the very beginning phases of understanding that

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00:55:47.340 --> 00:55:48.600

Ana Bonaca: That's very exciting.

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00:55:49.620 --> 00:55:57.390

Ana Bonaca: Just like this intercut structure of the clouds. The others seems to be a lot of information there. And we're going to allow asked

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00:55:59.250 --> 00:56:12.420

Ana Bonaca: If you could talk more about the observer dampening of the sine wave feature is this starts to reflect the internal dissipation in the guests. If so, do we expect associated shock features. And is there any way to see that.

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00:56:14.460 --> 00:56:27.810

catherinezucker: That's a great question. It's also a question I can't give you a, like a totally full answer to. So one of the things that we want to look at is whether we also see the damping and the stars.

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00:56:29.250 --> 00:56:31.890

catherinezucker: So I don't think this is a shock feature. I think that

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00:56:33.060 --> 00:56:39.060

catherinezucker: The way to tell this in particular is. So Gus being who might be on this call actually is.

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00:56:39.660 --> 00:56:50.550

catherinezucker: He's working on these new simulations called Milky Way in a bottle, where he actually will have able to model the stars and the gas and actually be able to collide things with our galaxy and figure out whether

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00:56:51.000 --> 00:57:00.510

catherinezucker: With this sort of collision you would expect this dampening to happen. And so right now, given that we really only know the morphology of the gas and actually haven't done any

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00:57:01.350 --> 00:57:09.780

catherinezucker: Detail comparisons with simulations yet. And there's really is no simulations actually modeling the gas phase of this sort of damping pattern.

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00:57:10.140 --> 00:57:21.840

catherinezucker: I think it's too soon to tell, but we should know, again, we have better kinematics from Gaia and we actually have these detail comparisons that we're really excited to work with us and marsan in the coming years. Yeah.

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00:57:23.250 --> 00:57:29.370

Ana Bonaca: Sounds great. This is a great way to to close the seminar.

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00:57:30.660 --> 00:57:39.540

Ana Bonaca: Of our theory and computation and connected back to the physical simulations offs star formation of those small scales.

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00:57:40.890 --> 00:57:45.900

Ana Bonaca: Looks like we're kind of out of time. If you have more questions, please.

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00:57:47.310 --> 00:57:52.770

Ana Bonaca: Send them to on their respective tracks. So the current in, and Catrin on Slack.

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00:57:53.820 --> 00:58:07.230

Ana Bonaca: Thank you all for coming. Thank you to our speakers for for ya sharing these wonderful results with us. And yeah, looking forward to hearing more from you in the future. Thank you.

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00:58:07.560 --> 00:58:08.610

Morgan Elowe MacLeod: Thank you so much.

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00:58:09.060 --> 00:58:11.490

catherinezucker: Thanks for hosting guys, it's great. Thanks.

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00:58:14.640 --> 00:58:15.330

Morgan Elowe MacLeod: Bye everyone.