WEBVTT

1
00:00:07.470 --> 00:00:09.300
Morgan Elowe MacLeod: Yes, and

2
00:00:11.160 --> 00:00:13.889
Morgan Elowe MacLeod: We're really grateful to have you. And we're excited to

3
00:00:15.150 --> 00:00:21.630
Morgan Elowe MacLeod: Hear today but supernova and or not and about planets and

4
00:00:23.100 --> 00:00:32.460
Morgan Elowe MacLeod: And have some great discussion. So the format is our speakers will talk for about 20 minutes each, and then we'll have time for about 10 minutes of question that's well try to finish.

5
00:00:33.570 --> 00:00:34.380
12 o'clock.

6
00:00:35.820 --> 00:00:45.300
Morgan Elowe MacLeod: Yes. Our first speaker today is Jennifer Enders Jennifer is a researcher at the University of Arizona, she is an expert on

7
00:00:46.320 --> 00:00:56.370
Morgan Elowe MacLeod: Following all things transients in the night sky. But I think your, your specialty that has evolved has has really become

8
00:00:59.550 --> 00:01:09.030
Morgan Elowe MacLeod: Explosions where there is lots of other material around so it's all sort of these bizarre luminous supernovae that we'll get to hear about today.

9
00:01:10.170 --> 00:01:16.560
Morgan Elowe MacLeod: But for this. You're a postdoc, and in a couple places and you did your PhD.

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00:01:17.910 --> 00:01:21.990
Morgan Elowe MacLeod: At LS view and we're delighted to have you here today. Thank you for

11

00:01:23.070 --> 00:01:28.020
Morgan Elowe MacLeod: Navigating the time difference and getting up early. I hope you weren't observing last night.

12
00:01:30.480 --> 00:01:33.570
Jennifer Andrews: Unfortunately, I don't want us on the mountains yet, but we're doing remote stuff. Yeah.

13
00:01:33.690 --> 00:01:36.000
Jennifer Andrews: Ice cubes are handling that right

14
00:01:37.320 --> 00:01:38.520
Morgan Elowe MacLeod: Well, thank you so much.

15
00:01:39.660 --> 00:01:43.500
Jennifer Andrews: Great. All right. Let's share the screen.

16
00:01:48.780 --> 00:02:08.520
Jennifer Andrews: All right. Yes. And like a Morgan said, I am at University of Arizona where I started as a postdoc with Nathan Smith and, as often happens, I think when everyone gets to Tucson. No one really wants to leave. And so we find reasons to stay around for as long as you can.

17
00:02:10.410 --> 00:02:24.510
Jennifer Andrews: And when working with Nathan Smith, you end up whether you want to or not working on a two car and massive stars and things that lose a lot of mass prior to ending their life.

18
00:02:25.560 --> 00:02:35.850
Jennifer Andrews: So this, we're not staring it. There we go. So today, I'm just going to talk about supernova. Let me start my timer so that I do not run over.

19
00:02:37.950 --> 00:02:52.920
Jennifer Andrews: About supernova imposters and the eruptions of massive stars. I am a complete observational astronomer so theory is not in my wheelhouse, but I will gladly supply theorists with any observations, they want

20
00:02:54.360 --> 00:02:56.490
Jennifer Andrews: So to start off with.

21
00:02:58.110 --> 00:03:00.300

Jennifer Andrews: Are you not going to advance. Okay. We have to click

22
00:03:01.650 --> 00:03:04.710
Jennifer Andrews: Oh, now I can't see my title slide. There we go.

23
00:03:05.790 --> 00:03:10.380
Jennifer Andrews: Um, so some of you may or may not have seen this plot by monsey before

24
00:03:11.520 --> 00:03:27.300
Jennifer Andrews: Where we have absolute magnitude and timescale of various types of transients. These are if you see. So absolute magnitude. So towards the top we have our thermonuclear and then our core collapse supernova, and then down to the bottom, all kinds of interesting

25
00:03:28.890 --> 00:03:35.580
Jennifer Andrews: Recurrent and or no Bay and classical Nova and all that sort of stuff. And then everywhere in between, say, between minus 10

26
00:03:36.780 --> 00:03:46.380
Jennifer Andrews: Absolutely magnitude of my as tend to maybe minus 14 or 15 are kind of what we dug gap transients and you can see a few examples. Well,

27
00:03:46.860 --> 00:04:00.870
Jennifer Andrews: At seven, eight, not a get friends yet, but it's on the kind of the fainter end of the quarter club supernovae, and then the beautiful be a great mom and ate a car here in sort of a BB region. I'm another

28
00:04:02.550 --> 00:04:11.100
Jennifer Andrews: So they're called sort of gap transits because there are the gap between classical innovate and core clubs supernovae, but they are often

29
00:04:12.600 --> 00:04:23.520
Jennifer Andrews: Referred to as supernova imposters they're sort of interchangeable and depending on who you ask. And what day it is. They can be sort of sub divided into

30
00:04:23.850 --> 00:04:38.490
Jennifer Andrews: Three different categories. And you'll see this plot, again, so we can discuss which which types of transients refer to what type of object, the sort of the very simple picture is that we can break down these gap transients these supernova imposters

31
00:04:39.540 --> 00:04:54.150
Jennifer Andrews: Into sort of three camps, one being lbs. Massive blue stars that variable. Usually, these are the super Eddington interruption. So the really big eruptions, where they get brighter by more than a magnitude

32
00:04:55.500 --> 00:05:11.790
Jennifer Andrews: More than one or two magnitudes. These were kind of the generally the first sort of imposters that were noticed. And so often super I've been pestering LB is used interchangeably, but I'm trying to make the distinction here that they are different.

33
00:05:13.530 --> 00:05:18.690
Jennifer Andrews: And then you have the luminous reading obey read and obey, which are

34
00:05:19.830 --> 00:05:25.860
Jennifer Andrews: Generally we think merger candidates larger events common of local events. And then finally, these

35
00:05:26.730 --> 00:05:42.480
Jennifer Andrews: Intermediate luminosity red transients I also call them 2008 as, like, because it's easier for me to remember which instead of trying to figure out what the acronym means and it's based on the 2008 is sort of the first object. The canonical object that we

36
00:05:43.560 --> 00:05:55.620
Jennifer Andrews: Refer to and we think these come from low mass electron capture supernovae. Now as you can see on the bottom. These are these are optical spectra of these different events.

37
00:05:56.460 --> 00:06:08.520
Jennifer Andrews: And especially when they're first detected as you can notice if you are familiar at all with optical spectroscopy is they look almost identical. So when you discover a transplant.

38
00:06:09.450 --> 00:06:19.140
Jennifer Andrews: And you take the spectrum and you try to classify it often if we were to look at just the cross section here we see these nice

39
00:06:20.460 --> 00:06:30.960
Jennifer Andrews: Strong narrow bomber lines h alpha sometimes H beta occasionally some calcium lines but early on. They're almost indistinguishable. So often when these are discovered there just put out

40
00:06:31.440 --> 00:06:41.640
Jennifer Andrews: an astronomer telegram or various other events as a interacting supernova or led eruption sort of the two camps are put into and not until we get

41
00:06:42.600 --> 00:06:46.770
Jennifer Andrews: Additional spectra and light curves can we sort of figure out where they fit.

42
00:06:47.490 --> 00:07:00.180
Jennifer Andrews: Into the whole scheme of things, because as we'll see in a second. A lot of these also span a wide range of absolute magnitude. So that even makes it harder without having an evolution with time, figure out what's going on.

43
00:07:02.040 --> 00:07:11.820
Jennifer Andrews: So the major LB V eruptions. The first class. And what I'm going to kind of talk about the most is in this region here. So the, the timescale is

44
00:07:12.900 --> 00:07:25.530
Jennifer Andrews: How long it takes to decline one magnitude, and I think it's usually the our band. And so you can see how movies can last a long time and they sort of run the gamut.

45
00:07:26.610 --> 00:07:40.230
Jennifer Andrews: In the Fall supernova imposter range, like I said, they're from massively progenitors the super addict interruptions. So the other event or the restaurant disruptions that are sort of, you know, one to two magnitudes. They're very

46
00:07:41.220 --> 00:07:47.190
Jennifer Andrews: Small, the most important thing I think is that they survived the event. So the light curves.

47
00:07:48.120 --> 00:07:57.090
Jennifer Andrews: As you can see at the bottom corner here. These are. It's a car piece of need quite a few lbs having these massive eruptions and you can see for

48
00:07:57.750 --> 00:08:04.920
Jennifer Andrews: Thousands of days afterwards. It takes a while for it to fade it can take a while for the LPP to fade.

49
00:08:05.850 --> 00:08:22.680
Jennifer Andrews: And it does survive the event, you need a car is an example. It's still there, but once again the spectral click interacting superhighway. So it's hard to distinguish at first because you can see absolute magnitude wise it kind of runs the whole the whole gamut here.

50
00:08:24.570 --> 00:08:31.560
Jennifer Andrews: Now the intermediate luminosity transients but I'll our t's are the 2008 as like

51
00:08:32.970 --> 00:08:43.920
Jennifer Andrews: An effect. You can see like her 2008 as here. I'm like I said, we think these are come from lower mess stars. They're super AG bees that have some electron capture

52
00:08:45.120 --> 00:08:47.520
Jennifer Andrews: That come from electron capture supernovae.

53
00:08:48.750 --> 00:08:52.020
Jennifer Andrews: And so they are terminal there shouldn't be anything left

54
00:08:53.310 --> 00:09:00.930
Jennifer Andrews: There usually have destined shouted progenitors so that you don't find the progenitor and the optical if you happen to have serendipitous.

55
00:09:02.280 --> 00:09:18.150
Jennifer Andrews: Imaging beforehand. You can usually find them in the eye, are particularly if you have Spitzer imaging, once again, they're spectra look like interacting supernovae, but they they fade quite quicker than the LR tease.

56
00:09:20.340 --> 00:09:26.730
Jennifer Andrews: And just keep in mind where I say they usually almost always have Dustin tried to progenitors because that's sort of the whole

57
00:09:27.750 --> 00:09:32.730
Jennifer Andrews: crux of my talk today. And then finally, luminous read obey

58
00:09:34.680 --> 00:09:37.140
Jennifer Andrews: Their brighter than red nose.

59
00:09:38.160 --> 00:09:50.160
Jennifer Andrews: And so they're called luminous or no way we're so we're very good at naming things generally, sort of, you know, with the three month particular and then other mergers.

60
00:09:51.330 --> 00:10:08.520
Jennifer Andrews: They were kind of put them this lower magnitude regime, but we've been finding over the years that you can actually have luminous read nobody that are quite quite bright and like I said, they think they're mergers and or the common objection. They can be both low and high mess stars.

61
00:10:09.630 --> 00:10:11.280
Jennifer Andrews: One very distinct

62
00:10:12.390 --> 00:10:22.920
Jennifer Andrews: Characteristic why you need to keep following these is there like hers generally have multiple peaks and you can see down here. There's a couple so be three mind has multiple peaks.

63
00:10:23.580 --> 00:10:31.410
Jennifer Andrews: But a couple of other objects. There's a first a red peak and our first one picking it up, often called the blue and the red peak.

64
00:10:33.150 --> 00:10:42.390
Jennifer Andrews: And the peaks and be separated, which we think, and I'm not going to go into too much here, but based on you know the masses of the of the stars.

65
00:10:43.560 --> 00:10:48.810
Jennifer Andrews: So that's a good predictor there that it's it's a merger event.

66
00:10:50.340 --> 00:11:01.560
Jennifer Andrews: So sort of what I want to focus on is can some or all of these, these 2008 is like they intermediate al RTS

67
00:11:03.120 --> 00:11:10.800
Jennifer Andrews: Could instead of being these low mass a TV stars, can they be dusty massive stars, but maybe with the interesting viewing angle.

68
00:11:11.820 --> 00:11:25.770

Jennifer Andrews: Or in other words, can some of the three different types of gap transients blurred lines between can you have multiple types of can you have an LB be and I'll our team.

69
00:11:28.110 --> 00:11:35.070
Jennifer Andrews: And the motivation for this is an object that we found in

70
00:11:36.150 --> 00:11:43.620
Jennifer Andrews: The near will nearby about 10 mega parsecs in 74 so you can see on the rights beautiful Gemini image there.

71
00:11:44.670 --> 00:11:51.930
Jennifer Andrews: And it was actually an object that was discovered in Switzerland. So if you see down the bottom corner the

72
00:11:53.250 --> 00:12:11.130
Jennifer Andrews: May 17. It was actually it was discovered on in July and. We scrounge back and went through the archives. And sure enough, it was actually detected, both in Spitzer and an HST images.

73
00:12:12.360 --> 00:12:19.380
Jennifer Andrews: Interestingly, it was behind the sun in in May. So we didn't catch it on the ground when it was bright and the optical

74
00:12:19.860 --> 00:12:31.110
Jennifer Andrews: But thankfully Switzer doesn't have to worry so much or didn't have to worry so much about what us as people from the ground could see it was able to catch it earlier. So we think we got the maximum in the in the mid I are here.

75
00:12:32.280 --> 00:12:41.700
Jennifer Andrews: But you can see that on the first panel is HST imaging in the I band. And you can see the progenitor and the top and

76
00:12:42.570 --> 00:12:50.250
Jennifer Andrews: On the bottom, this is the detection after the eruption. And then the little panels are the Spitzer images here.

77
00:12:50.970 --> 00:13:06.660
Jennifer Andrews: But what's really interesting is that because I'm saying before, is very well. So a galaxy. There's been at least three other supernova in it that we know of. There was a ton of archival data. And so we poured through all of that.

78
00:13:07.830 --> 00:13:13.890
Jennifer Andrews: And found not only archival HST data but collaborators.

79
00:13:15.180 --> 00:13:26.970
Jennifer Andrews: Actually had a whole bunch of deep LGBT data so large vascular telescope data and we were able to reconstruct a light curve of the progenitor for over 6000 days.

80
00:13:27.900 --> 00:13:38.010
Jennifer Andrews: So this is the combination of HST and LGBT data and the little thing to kind of the, the Spencer Spencer like her up at the top, those are mostly

81
00:13:38.970 --> 00:13:47.160
Jennifer Andrews: upper limits. Right. The detection range. This thing is 10 mega parsecs away, it's you know, it's pretty far and it's on the fainter and so it's not a super obey

82
00:13:49.260 --> 00:13:55.800
Jennifer Andrews: But there doesn't seem to be any major outburst from 2002 on. So, this thing's been pretty pretty stable.

83
00:13:57.210 --> 00:14:07.890
Jennifer Andrews: And then somewhere we so this dashed line here indicates our may 17 Spencer point. So we're just calling that the max, give or take a few weeks.

84
00:14:09.090 --> 00:14:24.870
Jennifer Andrews: Then it just brightened from quite a few magnitudes. As you can see here in the image and then it started to decline. So it was really interesting that we had this fantastic data set. And as I mentioned before, these

85
00:14:25.890 --> 00:14:36.660
Jennifer Andrews: Uh, these IoT types of objects have never had progenitors scene and the optical so we didn't immediately assume that it was that, type, type of object.

86
00:14:38.460 --> 00:14:43.020
Jennifer Andrews: But then when we got looked at the spectroscopy us very interesting

87
00:14:44.160 --> 00:14:52.530

Jennifer Andrews: They show only hydraulic the bomber lines hydrogen here and calcium lines and nothing

88
00:14:53.550 --> 00:15:00.180
Jennifer Andrews: Is fairly flat continuum. It seemed to indicate interaction, because there's no piecing the absorption or anything like that.

89
00:15:01.800 --> 00:15:18.330
Jennifer Andrews: But and here on the right is subsample of these IoT. So there's 2008 is here. And while it was classified as sort of a two in are interacting supernova or nobody, you know, it could be other things. So we kept following it.

90
00:15:20.160 --> 00:15:28.830
Jennifer Andrews: And it does have characteristics that look quite like these 2008 subjects. Interestingly, there was a serendipitous.

91
00:15:29.400 --> 00:15:46.830
Jennifer Andrews: muse VLT spectrum of the progenitor beforehand. So we actually have a progenitor spectra from a couple of months before explosion which was really interesting and allowed us to see that not only with time has the hydrogen shaped not changed much.

92
00:15:48.450 --> 00:15:54.600
Jennifer Andrews: But that there was already some sort of interesting physics going on with the progenitor there.

93
00:15:56.040 --> 00:16:00.270
Jennifer Andrews: But it also hardly changed with time. Okay, that was was at my five minute bell

94
00:16:02.880 --> 00:16:06.840
Jennifer Andrews: And like I said there was no outbursts and the decade prior to eruption. And here are some examples.

95
00:16:06.960 --> 00:16:14.700
Jennifer Andrews: Some examples of other types of I'll parties. These are in sort of the mergers and lbs. And so it can be

96
00:16:15.900 --> 00:16:21.210
Jennifer Andrews: Plotting up against the light curves, it could be quite a few different types of objects.

97

00:16:23.580 --> 00:16:25.800
Jennifer Andrews: But this is I think really the interesting part.

98
00:16:27.030 --> 00:16:31.830
Jennifer Andrews: We plot up some some CMT s here. So this is the HST

99
00:16:32.970 --> 00:16:46.170
Jennifer Andrews: 336 and 555 against the 336 and of course these are not going to give us exact masses. We aren't these are you know single star models and but it gives us an idea of what the mass of the progenitor may be

100
00:16:47.220 --> 00:17:02.820
Jennifer Andrews: And if we change the extinction, which we didn't give it, we can't quite quantify because of multiple things. But one being if there's dust immediately around the object, it can destroy it while it gets brighter. It can also

101
00:17:04.410 --> 00:17:12.090
Jennifer Andrews: Mask any of our normal lines we use to sort of measure what the extinction is. But basically, depending on how much extinction. We apply

102
00:17:13.440 --> 00:17:15.990
Jennifer Andrews: We can get masses, ranging from 13 to 58

103
00:17:17.040 --> 00:17:23.280
Jennifer Andrews: And the main picture to pull away here is that it's not a low mass star. This is a massive star and it's blue.

104
00:17:24.420 --> 00:17:44.430
Jennifer Andrews: And because we had so much little early time deep HST data of the progenitor I thought it was really interesting that depending on what epic. So in the different color circles are different epics what epic you actually observe and use to determine the mass, it gave you a slightly different

105
00:17:45.570 --> 00:17:47.610
Jennifer Andrews: Mass and even sort of

106
00:17:48.840 --> 00:17:52.110
Jennifer Andrews: Evolutionary state which sort of cautions against

107
00:17:54.120 --> 00:18:10.260

Jennifer Andrews: Using just one epic, especially if you have only one or two color to classify your the mass of your object. But hey, we can only use what we have. So thankfully we had a embarrassment of riches and progenitor data for the sky.

108
00:18:12.240 --> 00:18:26.520
Jennifer Andrews: But sort of the, the final takeaway. I guess we might show that in a car video is that this really looks like that. It is a hot blue massive star that resembles a

109
00:18:27.390 --> 00:18:42.720
Jennifer Andrews: Transient class that we think come from low mass very dusty electron capture supernovae types. So 2008 s and in DC 300 ot here and the teal and the purple or the or the

110
00:18:43.440 --> 00:18:52.260
Jennifer Andrews: Canonical members there. And while our object is much much brighter and the optical it's roughly the same brightness in the IR

111
00:18:53.190 --> 00:19:12.480
Jennifer Andrews: And that led us to think and bad along with the morphology of the emission lines. So over here is the Java mission line Carell IS HERE IN THE BLACK AND THEN HE or some other 2008 s like objects. So it's a little bit faster. And it's got kind of a interesting shape.

112
00:19:13.950 --> 00:19:17.370
Jennifer Andrews: But that led us to think that maybe what we're seeing is

113
00:19:18.510 --> 00:19:29.940
Jennifer Andrews: The same phenomenon but from a different viewing angle so if if dust and the CSM or is around the star sort of in a disc or or Taurus.

114
00:19:30.690 --> 00:19:43.050
Jennifer Andrews: And we happen to look at it. Paul on edge on, it'll be bright in both the optical and the infrared if we happen to view this object from edge on it would be obscured and the optical but very bright and the IR

115
00:19:43.590 --> 00:19:54.090
Jennifer Andrews: So you could have a bright optical and I are progenitor if you just happen to be looking, you know, down the pole this object and

116

00:19:54.360 --> 00:20:09.210
Jennifer Andrews: To sort of summarize that the different viewing angles. If you're looking through different columns of the same asymmetric CSM you can have it can look like you have to observational classes, but they're really the same phenomenon just coming from

117
00:20:10.230 --> 00:20:22.530
Jennifer Andrews: The viewing angle that you are are sort of looking at so if you assume spiritual cemetery, then you would think there were two different viewing class or two different types of

118
00:20:23.220 --> 00:20:32.430
Jennifer Andrews: Observational classes, but in fact, it could be just coming from one event. And so I think we do I still have time

119
00:20:33.930 --> 00:20:34.410
Jennifer Andrews: Yes.

120
00:20:36.030 --> 00:20:36.720
Jennifer Andrews: So,

121
00:20:36.960 --> 00:20:47.040
Jennifer Andrews: I'm to what is at 2019 Carell so it could be a bunch of things, these are the different sort of classes and

122
00:20:47.520 --> 00:20:55.470
Jennifer Andrews: We think we don't know if it or survived the bet the event. So that's sort of the big thing. So of course we need later time to see your large telescope

123
00:20:55.800 --> 00:21:14.130
Jennifer Andrews: Observations to see if it's there, particularly in the blue because if it is an LB be eruption or a merger of some sort. It may have gotten harder but fainter in the red band. So we need some UV or you band images to see

124
00:21:15.630 --> 00:21:28.800
Jennifer Andrews: So we aren't exactly sure what it is, but we think it is a map. We know it is a massive blue star that mimics a 2008 us like event. And the reason sort of to tie this all together.

125
00:21:30.390 --> 00:21:38.880
Jennifer Andrews: Because I can't, like I said, not talk about it a car is I'm going to skip through these. I was very ambitious is that recently.

126
00:21:39.480 --> 00:21:58.800
Jennifer Andrews: Nathan and I with a bunch of collaborators have a paper out using the light echoes from a two car where we make a conjecture that it can possibly come from a merger scenario so down the bottom corner is is sort of the video of of what we think one possibility could be

127
00:21:59.910 --> 00:22:06.420
Jennifer Andrews: Words, a two phase merger scenario and and that it started out starts out as a tertiary

128
00:22:08.160 --> 00:22:25.200
Jennifer Andrews: And then there's a lot of mass transfer there's merging. There's a miraculous nebulous Oculus nebula there and that basically what happens is there's the lot of CSM interaction that's causing sort of the second bright part of the sustained peak.

129
00:22:27.000 --> 00:22:28.620
Jennifer Andrews: And this can be sort of

130
00:22:29.640 --> 00:22:34.740
Jennifer Andrews: Mapped by our light echo spectra. So to sort of

131
00:22:36.120 --> 00:22:45.360
Jennifer Andrews: summarize everything can be a massive blue have a massive blue progenitor if you look hard enough. So it seems like all three observational classes.

132
00:22:45.990 --> 00:23:06.750
Jennifer Andrews: Can have these massive blue stars, or at least we're finding evidence of it and that we think that another LB eruption superhero imposter eruption could be explained by a merger as well. So I will. I'm going to leave it on the video and leave it there.

133
00:23:13.860 --> 00:23:14.250
Ana Bonaca: Yeah.

134
00:23:16.890 --> 00:23:21.180
Ana Bonaca: It was great. Thanks. Also, yeah. Thanks for playing good movie. It's very

135
00:23:21.840 --> 00:23:22.560
Ana Bonaca: A lot of fun.

136
00:23:23.550 --> 00:23:25.350
Jennifer Andrews: Yeah, exactly. Yeah.

137
00:23:25.470 --> 00:23:26.880
Ana Bonaca: I'm glad I got it.

138
00:23:27.930 --> 00:23:37.680
Ana Bonaca: But that's a, that's a pretty neat idea of like all of these being same class of optic just seeing different viewing angles.

139
00:23:37.860 --> 00:23:38.310
Jennifer Andrews: Right, so

140
00:23:39.870 --> 00:23:50.460
Jennifer Andrews: It's probably not that bad is exactly what's happening. They're all for the exact same, but we can think about that, you know, maybe it isn't. There are other you know ways to explain it. Yeah.

141
00:23:51.570 --> 00:23:53.250
Ana Bonaca: Yeah, but it's, uh, yeah, definitely.

142
00:23:54.540 --> 00:24:00.210
Ana Bonaca: It's nice having like tying things together a physical picture. And so I just wondering

143
00:24:01.740 --> 00:24:08.550
Ana Bonaca: Can we are dear predictions of sort of what the covering fraction of this circumstance or

144
00:24:09.240 --> 00:24:28.050
Ana Bonaca: Dust is and and does that sort of kind of back of the envelope calculation workouts with the sort of number of these events we have in different categories. So we have an expectation of how many we should be seeing at which viewing angle. And if the numbers work out roughly

145
00:24:29.040 --> 00:24:34.740
Jennifer Andrews: Yeah, so, um, it's, it's possible. The problem, of course, is we are you know

146
00:24:36.270 --> 00:24:39.540
Jennifer Andrews: Our sample is limited and a lot of them are galactic

147
00:24:41.280 --> 00:24:54.510
Jennifer Andrews: But if you do look at massive stars. A lot of them. Most of them are in some sort of multiple system and in instances where we can actually map or look around.

148
00:24:55.620 --> 00:25:01.950
Jennifer Andrews: Especially the high mass, mass all stars. It does often seem that the

149
00:25:03.180 --> 00:25:17.520
Jennifer Andrews: That the circumpolar material is it's some sort of asymmetric, whether it's by local whether it's you know CSM or disc or tourists. So it's definitely it fits. I haven't done the numbers yet to see

150
00:25:19.050 --> 00:25:31.080
Jennifer Andrews: What is happening and the other side is that we're still observing, especially the group out of Ohio State looking at those 2008 types of objects to make sure that they are completely gone.

151
00:25:31.890 --> 00:25:41.040
Jennifer Andrews: And an interesting thing is they do seem terminal. There doesn't seem to be anything left there but also

152
00:25:42.540 --> 00:25:58.740
Jennifer Andrews: There is a ton of dust right so you can hide a lot there as well. They that does seem sort of consistent that they are that those were terminal events which, you know, maybe there's just two different ways you can get the same observational characteristic

153
00:25:59.760 --> 00:26:05.370
Jennifer Andrews: But of course it could also just be way more dust than we have in the object that we observed. Yeah.

154
00:26:06.990 --> 00:26:17.700
Ana Bonaca: So yeah, it sounds like it would be really helpful to have like larger samples, as always, and Morgan had a question sort of along those lines of

155
00:26:18.780 --> 00:26:25.890
Ana Bonaca: If LSD will be useful in district guard where the depth and cadence will be sufficient for

156
00:26:27.510 --> 00:26:35.160

Ana Bonaca: Nearby transit is like the 18 2019 k r l that you, you talked about here.

157
00:26:36.150 --> 00:26:42.210
Jennifer Andrews: Yeah, I think so. Especially, you know, you'll be able to at least with the light curves. Throw them up on the

158
00:26:43.440 --> 00:26:47.250
Jennifer Andrews: On that transit on that map and sort of see where they fall

159
00:26:48.330 --> 00:27:01.680
Jennifer Andrews: Yeah, so I think LSC it's going to be, you know, super useful in that now whether how you, it's going to be mined out to then go and look for progenitors and map, you know what you can find. Based on the light curves.

160
00:27:02.700 --> 00:27:08.250
Jennifer Andrews: You know that's that's what everyone's figuring out right now, right, like how to find the best juiciest transients

161
00:27:08.940 --> 00:27:22.410
Jennifer Andrews: But yeah, I think it'll be super helpful and will will probably really fill in this whole, this whole map here and find all sorts of very weird stuff. But yes, I think number wise, it's really going to help us.

162
00:27:24.240 --> 00:27:37.470
Jennifer Andrews: Now, we won't have Spitzer, but hopefully with, I don't know exactly where we're going to be with AWS t and LSC overlap at all. But, you know, used in tandem it possible, those would be that would be very useful for this thing. Yeah.

163
00:27:39.660 --> 00:27:41.460
Ana Bonaca: Yeah, that's very exciting.

164
00:27:42.840 --> 00:27:44.520
Ana Bonaca: Guess. One other question.

165
00:27:44.550 --> 00:27:45.840
Ana Bonaca: Morgan had was

166
00:27:46.920 --> 00:27:52.080

Ana Bonaca: About the red message progenitors what kind of transcends those with previews.

167
00:27:52.950 --> 00:27:56.250
Ana Bonaca: Which one, sorry, the massive red stars.

168
00:27:57.240 --> 00:27:58.860
Jennifer Andrews: Oh, so the massive red stars.

169
00:28:00.570 --> 00:28:01.620
Jennifer Andrews: Right, so

170
00:28:02.940 --> 00:28:05.220
Jennifer Andrews: Usually our massive red stars are core clap super

171
00:28:08.610 --> 00:28:09.180
Jennifer Andrews: Those are

172
00:28:09.300 --> 00:28:25.110
Morgan Elowe MacLeod: Totally fair with the idea that like maybe if all of these kind of like blue. And blue ish progenitors seem to produce this variety of transients is there may be a variety of transients coming from red or progenitors also

173
00:28:25.770 --> 00:28:27.870
Morgan Elowe MacLeod: Right. What, where do those show up.

174
00:28:27.900 --> 00:28:29.400
Morgan Elowe MacLeod: In my face face.

175
00:28:30.210 --> 00:28:42.750
Jennifer Andrews: Those yeah like I said those are generally our car clubs supernovae. So the, I think the, the biggest thing here is that with the very blue stars. There are two channels that they're supermassive or

176
00:28:43.380 --> 00:28:58.320
Jennifer Andrews: Their normal low mass binary mergers that turn out to end up looking blue. So they already have a whole bunch of weird circumstance material and weird dynamics going on and that sort of makes it hard to distinguish between

177
00:28:59.880 --> 00:29:08.100

Jennifer Andrews: I guess cause and effects if if the LED is caused by a merger or if it's caused by its own massive bleakness, I guess.

178
00:29:09.180 --> 00:29:28.200
Jennifer Andrews: If that helps. And generally, the red ones. I guess this technically a super ATP star would be quite read and then that's going to be the, the other end 2008 as like electron capture supernovae. So, but I think in the end if you're read you end up being terminal.

179
00:29:29.820 --> 00:29:32.430
Jennifer Andrews: Your blue, you have a chance of reviving yourself.

180
00:29:34.020 --> 00:29:37.770
Ana Bonaca: So just ended on on kind of a very

181
00:29:38.910 --> 00:29:51.690
Ana Bonaca: early universe note and hopefully future with AWS, see. So these are all method stars and it will be luminous and hopefully very abundant in the early universe and you showed us that these

182
00:29:52.560 --> 00:30:05.130
Ana Bonaca: local variables like our sustain that like these high luminosity for a long time. So presumably they will have a huge impact on their early like those early galaxy. So

183
00:30:06.690 --> 00:30:13.350
Ana Bonaca: They expect like this. Are they will they be detectable like a cruise ships or whatever, they're like 10 or so.

184
00:30:13.380 --> 00:30:26.820
Jennifer Andrews: Yeah. Yeah, I believe so. Yeah. I mean, they're and they're quite dusty they've lost a lot of mass, mass moves or the moves away cools off when we see it in the IR so yeah beads are are quite big.

185
00:30:27.900 --> 00:30:41.010
Jennifer Andrews: I am ization and dust producing things so pretty sure we will see them to USD. I'm not a Heidi person. So I'm not exactly sure how far back. We can see them, but

186
00:30:42.060 --> 00:30:50.550
Jennifer Andrews: Yes, of course, massive stars have a lot of they may be smaller number, but they are mighty and what they do to their surrounding see

187

00:30:53.280 --> 00:30:56.010
Abraham Loeb: It might be difficult to see one at a time, but

188
00:30:58.080 --> 00:31:01.200
Abraham Loeb: You know, a number of them noticeable effect.

189
00:31:02.370 --> 00:31:02.880
Abraham Loeb: With redshift.

190
00:31:05.340 --> 00:31:14.670
Ana Bonaca: Yeah, so I think that's really important that they have this more physical pictures like channels deriving so that we can interpret those observations.

191
00:31:16.260 --> 00:31:18.270
Ana Bonaca: Very exciting stuff. Thank you so much.

192
00:31:20.910 --> 00:31:21.900
Morgan Elowe MacLeod: Wonderful. Thank you.

193
00:31:26.130 --> 00:31:38.700
Morgan Elowe MacLeod: Let's continue on to our second speaker Diana Powell, who is completing her PhD at UC Santa Cruz. She's also a Ford Foundation dissertation year fellow this year.

194
00:31:40.200 --> 00:31:48.780
Morgan Elowe MacLeod: And then as an expert really um I think how the chemistry and in the title micro physics of

195
00:31:49.650 --> 00:32:07.710
Morgan Elowe MacLeod: These environments around other stars, whether that's in production planetary atmospheres or protoplanetary discs really shaped what we observe. When we look at them and we're really excited to have you today and we're jealous of your background picture of Santa Cruz.

196
00:32:09.120 --> 00:32:10.830
Diana Powell: So I put it there. I bet you

197
00:32:13.230 --> 00:32:14.280
Diana Powell: Awesome. Thanks, Morgan.

198
00:32:14.820 --> 00:32:18.630

Diana Powell: So yeah, I'm Diana pedal and I'm a graduate student at UC Santa Cruz.

199
00:32:19.140 --> 00:32:28.350
Diana Powell: Santa Cruz finally looks like this picture again. So I thought I'd share it, and today I'm really excited to talk with you all about protoplanetary desks and sub solar atmospheres.

200
00:32:29.550 --> 00:32:35.760
Diana Powell: And in particular, I will be focusing on insights that we can gain from understanding these objects from the perspective of micro physics.

201
00:32:36.870 --> 00:32:44.280
Diana Powell: And so, for the purposes of this talk, micro physics will refer to the physics governing the evolution of small particles and the presence of gas.

202
00:32:50.970 --> 00:32:57.090
Diana Powell: So the key question behind all of my research is what is the origin evolution in nature of planets.

203
00:32:59.040 --> 00:33:02.700
Diana Powell: And so the picture of planet from nation that has emerged looks more or less like this.

204
00:33:03.870 --> 00:33:14.940
Diana Powell: So planets form and protoplanetary discs, either from the accretion of solids and gas or the gravitational collapse of material so protoplanetary discs constitute the building blocks of planetary systems.

205
00:33:16.050 --> 00:33:28.830
Diana Powell: And then once the protoplanetary disk dissipates a young planetary system remains and then as time progresses, the planetary system will evolve planets will find relatively stable orbits and the planetary atmospheres will also evolve.

206
00:33:30.690 --> 00:33:32.460
Diana Powell: Okay, so this is the general picture.

207
00:33:33.660 --> 00:33:37.290
Diana Powell: But what I really want to know is empirically. What is the answer to this question.

208

00:33:40.650 --> 00:33:45.960
Diana Powell: And we're all very lucky to be live at a time where we can actually observe each of these stages of planetary evolution.

209
00:33:47.040 --> 00:33:57.420
Diana Powell: So we can observe protoplanetary discs undergoing at the planet formation, like the PDS 70 system, shown here in the top right where you can see these two points that are thought to be giant planets undergoing accretion.

210
00:33:59.790 --> 00:34:05.520
Diana Powell: We can also observe young planetary systems directly, like the HR 8799 system shown in the bottom left.

211
00:34:06.900 --> 00:34:10.860
Diana Powell: And finally, we now have observations over 4000 evolved exoplanets.

212
00:34:14.940 --> 00:34:21.150
Diana Powell: So with all this data. This is really be era to start actively connecting planet formation to planetary characterization

213
00:34:22.320 --> 00:34:29.940
Diana Powell: And in particular, a promising Avenue forward is to connect the properties of exoplanet atmospheres, the properties of protoplanetary discs.

214
00:34:34.380 --> 00:34:41.490
Diana Powell: So when we look at observations of protoplanetary discs, we're looking at smaller screens and some different trace gas species.

215
00:34:42.720 --> 00:34:49.260
Diana Powell: And these recent observations are really spectacularly really resolved so they're gorgeous and there's lots of information.

216
00:34:49.830 --> 00:34:58.170
Diana Powell: But there are also often limited and particular that's due to a lack of direct probes of the primary disk properties such as the total mass in the system.

217
00:34:58.710 --> 00:35:07.050
Diana Powell: And then some of the detailed properties of the solid and gashes mass constituents. And so this is particularly in the mid plane, the planet forming regions of the desk.

218
00:35:09.390 --> 00:35:23.220
Diana Powell: And then when we look at detailed observations of young and evolved planetary systems were often looking at their atmospheres and similarly these observations are hindered by a passive sources such as clouds and he's is that can obscure planetary properties.

219
00:35:27.030 --> 00:35:35.400
Diana Powell: So to make the connection between protoplanetary disks and planetary atmospheres. We need better physical models to interpret current and upcoming observations.

220
00:35:36.600 --> 00:35:41.070
Diana Powell: And I will argue in this talk that maker physics will be really important player and making this connection.

221
00:35:42.120 --> 00:35:48.660
Diana Powell: And that make your physics may well be key to to really understanding the origin evolution and nature of planets.

222
00:35:52.410 --> 00:35:59.250
Diana Powell: Okay. So in this talk, I'll cover a lot of ground, but I'll start by talking about subsequent atmospheres, with a focus on clouds.

223
00:36:00.210 --> 00:36:14.040
Diana Powell: And then I'll move on to discussing the total mass and protoplanetary disks. And finally I'll spend them the most time in detail, bringing the previous two topics together through discussion of the evolution of carbon monoxide and protoplanetary this

224
00:36:17.580 --> 00:36:19.620
Diana Powell: Okay, so let's talk about clouds.

225
00:36:23.580 --> 00:36:27.750
Diana Powell: So we all have some intuition about clouds from our familiarity with clouds on Earth.

226
00:36:29.580 --> 00:36:35.310
Diana Powell: The clouds are important beyond her and are, in fact, the dominant capacity source and most planetary atmosphere.

227
00:36:37.290 --> 00:36:41.310
Diana Powell: Clouds important tracers of atmospheric physics, such as mixing and transport.

228
00:36:42.900 --> 00:36:46.740
Diana Powell: Clouds regulate the planetary climate be regulating ready to transfer and chemistry.

229
00:36:48.210 --> 00:36:51.450
Diana Powell: And clouds must be understood when determining atmospheric abundances

230
00:36:53.700 --> 00:37:02.940
Diana Powell: Also, often the clouds and an atmosphere are the only thing that we see. So, it is therefore an absolute necessity that we understand clouds were interpreting planetary atmospheres.

231
00:37:07.440 --> 00:37:16.470
Diana Powell: Okay, so getting this. There's a lot that we can learn about planetary atmospheres their studies of clouds. So it makes sense to understand how clouds form and evolved from first principles.

232
00:37:17.940 --> 00:37:23.430
Diana Powell: So on the right here I'm showing the example of someone might calculations of cloud properties and planetary atmospheres.

233
00:37:24.480 --> 00:37:29.400
Diana Powell: So I'm planning the mast into the cloud particles as a function of particle size and atmospheric pressure.

234
00:37:30.690 --> 00:37:33.780
Diana Powell: And here, each of the different colors indicate the different cloud species.

235
00:37:35.010 --> 00:37:48.000
Diana Powell: And all the properties of the cloud particles, shown here, such as the particle size distributions and vertical extensive the atmosphere are calculated from first principles. Their consideration of the micro physical processes that I've shown here on the left.

236
00:37:55.050 --> 00:38:01.620
Diana Powell: So by studying clouds from first principles. I can demonstrate how the metaphysical properties of clouds sheet atmosphere observations.

237
00:38:03.330 --> 00:38:12.930

Diana Powell: On the top right. I'm showing the impact of the cloud particle size distribution on the observed spectra exoplanet. And so in this case I'm looking at our model. Hot Jupiter.

238
00:38:14.190 --> 00:38:20.730
Diana Powell: And so in black. I'm showing a model transmission spectra for a Hot Jupiter with our fully resolved cloud particle size distribution.

239
00:38:22.290 --> 00:38:31.140
Diana Powell: And then on the same planet and blue I showing the transition spectra. If we take an average cloud particle size for each cloud species and conserve the total cloud mass

240
00:38:32.910 --> 00:38:44.520
Diana Powell: And as you can see, but the amplitude and the shape of the transmission spectra changes between these two cases really demonstrating that understanding the cloud particle size distribution is important when interpreting serve spectra.

241
00:38:46.770 --> 00:38:52.170
Diana Powell: And by studying clouds. This way I also consider barriers to cloud formation beyond thermodynamics

242
00:38:53.490 --> 00:38:57.930
Diana Powell: And this allows me to predict which cloud species are likely to dominate the observed spectra.

243
00:38:59.550 --> 00:39:07.320
Diana Powell: So on the bottom right here in black. I'm showing a different model transmission sector for Hot Jupiter we're including capacity from all the cloud species that form.

244
00:39:08.520 --> 00:39:16.680
Diana Powell: And grey I'm showing what the cloud, what the transmission specter would look like without the clouds. So you can already see how much impact clouds have and shaping observations.

245
00:39:18.450 --> 00:39:24.360
Diana Powell: And then in the different colors. I'm showing what the spectrum would look like if we only consider capacity from a particular cloud species.

246
00:39:25.500 --> 00:39:31.170

Diana Powell: And so in this case Sylhet clouds dominate the atmosphere capacity across a broad range.

247
00:39:36.780 --> 00:39:43.680
Diana Powell: So in addition to impacting spectra clouds me also service probes, the planetary properties such as the interior thermal structure.

248
00:39:45.480 --> 00:39:56.370
Diana Powell: So here I'm showing a mission capacities as a function of wavelength and atmospheric pressure for a planet with the same upper atmosphere structure. So temperature structure, but different internal thermal structures.

249
00:39:57.600 --> 00:40:01.410
Diana Powell: And here the dotted white line indicates that location. Will the clouds become opaque.

250
00:40:03.390 --> 00:40:08.880
Diana Powell: So for the high energy, high interview planet with the hotter interior clouds or pick as high as point one bar.

251
00:40:10.050 --> 00:40:15.990
Diana Powell: But for a cooler into your, your low entropy interior planet and the clouds are only a pic at around 10 bar.

252
00:40:17.580 --> 00:40:24.150
Diana Powell: So clouds. My best be able to service probes a planetary interiors, as they are sensitive to planetary properties across different skins.

253
00:40:28.890 --> 00:40:36.870
Diana Powell: And I've also shown the clouds are likely to enhanced observed atmosphere and homogeneity in certain cases and way that should be clearly visible with James

254
00:40:38.640 --> 00:40:53.880
Diana Powell: So here I'm showing to scale, when really I differences for Hot Jupiter in the case of clouds on the top and for cloud free atmosphere on the bottom. So you can look at these little to slices to see that that cloudy atmosphere has distinctly asymmetrical limb Radia

255
00:40:55.020 --> 00:41:09.300
Diana Powell: That is significantly if something's lens are significantly more and how much you need and homogeneous and and homogeneous and the

clear atmosphere case which also has limited symmetry, but this is just you temperature differences on this particular planet.

256
00:41:11.340 --> 00:41:17.340
Diana Powell: And so we've worked to develop a tool for probing this atmospheric homogeneity relatively cheaply using James lab.

257
00:41:22.140 --> 00:41:26.580
Diana Powell: And finally, micro physical clouds can be used to explain existing observations.

258
00:41:28.020 --> 00:41:37.140
Diana Powell: So here I'm showing the color manga to diagram for Brown doors with a relatively recently discovered sequence of very low gravity brown dwarfs highlighted here in yellow.

259
00:41:38.970 --> 00:41:48.810
Diana Powell: OK. So the model very low gravity so model very low gravity profiles with clear atmospheres lie in this region of the diagram, but we do not really observe any brown doors.

260
00:41:50.400 --> 00:42:05.190
Diana Powell: And if we model clouds in these atmospheres without metaphysics and the points like here, so they are much better than the clear cases I would indicate that clouds are shaping these observations, but here they start to become more clear at lower equilibrium temperatures

261
00:42:07.710 --> 00:42:11.670
Diana Powell: Then when we instead. Consider micro physical clouds those points like here.

262
00:42:12.960 --> 00:42:18.570
Diana Powell: And we can see a distinct shift towards the red region of the diagram, particularly for the cooler objects.

263
00:42:19.530 --> 00:42:30.810
Diana Powell: And something that is particularly encouraging about the micro physical results here as at the points. Follow the streets slope of the sequence down to the brightest regions where we are currently different objects, instead of carving off to the blue.

264
00:42:33.480 --> 00:42:39.810

Diana Powell: And so these results demonstrate that been scheme micro physical clouds naturally reproduce the very low gravity sequence of brown dwarfs.

265
00:42:45.090 --> 00:42:58.650
Diana Powell: Okay, so we discussed the importance of understanding clouds and substitute atmosphere which is important and constraining of all planets. And now for the remainder of this talk. Let's turn our attention to protoplanetary disks. So the locations of planet formation.

266
00:43:00.330 --> 00:43:05.400
Diana Powell: And I will start by talking about the interesting question of how much total mass is present in existence.

267
00:43:09.960 --> 00:43:18.000
Diana Powell: Okay. So the most common tracers of protoplanetary this properties are dust or trace gases. And so our focus on SEO gas.

268
00:43:19.110 --> 00:43:21.270
Diana Powell: And these are relatively easy to observe

269
00:43:23.040 --> 00:43:27.900
Diana Powell: But due to a lack of the direct probe of the main mass constituent which is h2 gas.

270
00:43:28.950 --> 00:43:32.700
Diana Powell: Previous measures of this mass have relied on some trees or to HDL ratio.

271
00:43:34.680 --> 00:43:45.810
Diana Powell: But we know that processes such as brain growth and drift. So when these dust particles grow and move aerodynamically the should alter the desk gas ratio from the typical is in value.

272
00:43:47.640 --> 00:43:56.670
Diana Powell: And several lines of evidence also suggests that gas they co. So, particularly in the commonly observed upper declares is depleted and discs.

273
00:43:58.080 --> 00:43:59.250
Diana Powell: So this begs the question,

274
00:44:01.890 --> 00:44:06.450

Diana Powell: How can you measure the total mass without an assumed tracer to HDL ratio.

275
00:44:08.700 --> 00:44:11.370
Diana Powell: And also what is happening to all of the CEO.

276
00:44:16.470 --> 00:44:22.500
Diana Powell: And so we began addressing these questions by considering recent multi wavelength observations of discs in the millimeter

277
00:44:23.940 --> 00:44:29.820
Diana Powell: So here I'm showing a visualization of observations put together by Sean Andrews as a disc Tw Hydra

278
00:44:31.050 --> 00:44:36.030
Diana Powell: So here these are all images of the same disk where it appears smaller and radius at longer wavelength.

279
00:44:37.860 --> 00:44:46.470
Diana Powell: And to introduce some terminology I refer to the maximum radius and with our mission at a particular wavelength, the cuts off as a desk line.

280
00:44:47.760 --> 00:44:52.050
Diana Powell: And, as others have suggested these observations, maybe signatures of particle drift.

281
00:44:56.460 --> 00:45:04.110
Diana Powell: So particles drift and desks, because the gas kills an outward pressure gradient. So this cause that there'd be a drag on the particles.

282
00:45:05.190 --> 00:45:09.930
Diana Powell: The straggler moves the angular momentum from the particles and causes them to inspire all towards their health star.

283
00:45:11.760 --> 00:45:20.970
Diana Powell: And so we can use these observations of particle drift to trace the aerodynamic properties of the observed particles and determine the total gas mask present and systems.

284
00:45:22.620 --> 00:45:33.330

Diana Powell: So we can do this. Following the simple equation shown here on the right. If we know several key quantities. So in particular, if we know the maximum radius and which particles of a given size are present.

285
00:45:34.800 --> 00:45:44.880
Diana Powell: And luckily, we can infer the particle size. If the observed wavelength, the corresponds to the primary particle size contributing to the observed emission, particularly at the outer edge.

286
00:45:46.260 --> 00:45:52.200
Diana Powell: And we can robustly measure the disk size to determine the radius in which these particles are the massively sized screens.

287
00:45:54.270 --> 00:46:00.900
Diana Powell: And this method is really nice because it allows us to derive the disk surface density without assuming a tracer to HP ratio.

288
00:46:01.800 --> 00:46:11.490
Diana Powell: And that's because we only care about the how fast these particle drifts these particles stripped so they're aerodynamic properties which depends on their size and not how many particles or press

289
00:46:16.710 --> 00:46:25.530
Diana Powell: So in my recent paper. We've applied this model to seven protoplanetary discs with previous millimeter observations that so decreasing disk real extent with wavelength.

290
00:46:26.730 --> 00:46:30.840
Diana Powell: And here I'm showing some of the observations for three out of the seven discs in our sample.

291
00:46:35.850 --> 00:46:42.360
Diana Powell: And so we can do a lot with this modeling. But one of the key things that we found is that this masses are larger than we initially expected

292
00:46:43.830 --> 00:46:53.880
Diana Powell: So here on the left. I'm showing total gashes surface densities and black for to have the discs in my sample. So here these black lines are the dust line derived service entities.

293
00:46:55.320 --> 00:47:01.320
Diana Powell: And I'm comparing the surface density to previous trees are derived service densities and the minimal muscle and IP law.

294
00:47:03.540 --> 00:47:12.150
Diana Powell: So the disks and our sample are nine to 27% of their hosts stellar masses. And so this is significantly more massive than the minimum muscle or nebula.

295
00:47:13.950 --> 00:47:22.170
Diana Powell: These discs are also to to 15 times more massive than estimates from optically then Dustin mission, assuming an ASM dusty gas ratio.

296
00:47:24.090 --> 00:47:24.510
Diana Powell: So,

297
00:47:24.600 --> 00:47:26.520
Diana Powell: Also for the leaders in our sample.

298
00:47:26.880 --> 00:47:33.540
Diana Powell: With results. Your mission our estimates are 340 and 115 times more massive than previously published

299
00:47:34.800 --> 00:47:40.800
Diana Powell: So we find that CEOs depleted from expected values. And that's your depletion. It's not uniform across different desks.

300
00:47:42.090 --> 00:47:55.680
Diana Powell: So these results indicate that dust as a more robust tracer of total mass because we uncover a reduced gas ratio that is consistent across our sample, while the CO2 he ratio berries more strongly and I'll come back to this in just a moment.

301
00:47:59.010 --> 00:48:05.010
Diana Powell: Okay, so this work led me to this new picture of desks or they may be more massive than previously, appreciate it.

302
00:48:06.030 --> 00:48:11.700
Diana Powell: So in this picture of the total dust mask is about the same, but the total gas mask is an order of magnitude larger

303
00:48:13.230 --> 00:48:19.140
Diana Powell: And this qualitative changes models of protoplanetary discs has significant implications for theories of Planet promotion.

304

00:48:19.590 --> 00:48:29.190
Diana Powell: And that's particularly true for any process or the dis mass or the amount of gas affects the evolution of solids any process that relies on those will be affected by this picture.

305
00:48:32.430 --> 00:48:42.300
Diana Powell: And so in my remaining time I'll turn my attention to discussing it CEO and discs. So we've discussed the total mass. But really what's happening to all the CEO.

306
00:48:43.470 --> 00:48:49.890
Diana Powell: And we really want to know the answer to this question because SEO has been used as a tracer for a broad range of fundamental this properties.

307
00:48:51.330 --> 00:48:58.110
Diana Powell: And answer this question, I'll combine the two methods that I use so far in this talk. So modeling clouds and modeling desks.

308
00:49:01.560 --> 00:49:07.170
Diana Powell: I'll just quickly set back and say that it's not just my modeling that indicates that SEO is depleted in discs.

309
00:49:08.610 --> 00:49:17.940
Diana Powell: So on the left here I'm showing the CEO abundance and the disclosure you Hydra as a function of radius as compared to the abundance that we would expect from observations of the interstellar medium.

310
00:49:19.470 --> 00:49:22.620
Diana Powell: So you can see that CO gas appears to be significantly depleted.

311
00:49:24.060 --> 00:49:26.580
Diana Powell: And the same is true if we look at large samples of desks.

312
00:49:27.600 --> 00:49:36.840
Diana Powell: So here I'm showing an almost survey at this and lupus for the expense several orders of magnitude and dust mass, but have fairly constant gas masses estimated from SEO.

313
00:49:38.370 --> 00:49:44.910
Diana Powell: So in short, we observed, much less the own discs than we would expect or then would be predicted using previous models.

314

00:49:48.270 --> 00:49:58.320
Diana Powell: So to address this problem. I'll couple my model for protoplanetary this properties with an adaptive version of the models that I used to study cloud formation and protocol in in planetary atmospheres.

315
00:49:59.910 --> 00:50:03.810
Diana Powell: And in this context I modeling the formation of ice on dust disks.

316
00:50:07.530 --> 00:50:15.030
Diana Powell: And what turns out to be particularly important in this modeling is that the nuclear fission and growth processes in the scheme include the Kelvin effect.

317
00:50:16.500 --> 00:50:24.270
Diana Powell: So the Kelvin effect is a surface tension effect that quantifies the stability of particles, they're considering the strength of the molecular surface bonds.

318
00:50:25.830 --> 00:50:35.520
Diana Powell: And I like to think about this in terms of geometry when ice molecule. Honestly, I have a small grand will not be able to molecular Lee bond to as many neighbors as it would on a large particle

319
00:50:37.350 --> 00:50:41.760
Diana Powell: And so in short the calming effect causes large particles nuclear and grow more easily.

320
00:50:45.900 --> 00:50:51.450
Diana Powell: So the particle sizes are important here because they regulate the level of depletion of gashes SEO.

321
00:50:53.580 --> 00:51:02.280
Diana Powell: So if we approximate a disc temperature structure as shown here on the left where the disc is ice thermal until it reaches a height, where the surface layer heating as efficient.

322
00:51:03.480 --> 00:51:06.750
Diana Powell: And the mid lane, the disc is called enough for us to form under screens.

323
00:51:08.070 --> 00:51:10.350
Diana Powell: So there will be a region and the desk. Where is a stable.

324
00:51:11.580 --> 00:51:13.560
Diana Powell: And then a region where evaporation could occur.

325
00:51:15.510 --> 00:51:24.510
Diana Powell: So if the ice particles that form in the mid plan are small, then it could be laughed at the upper regions and evaporate such that CEO gas is not significantly depleted.

326
00:51:26.400 --> 00:51:31.440
Diana Powell: On the other hand, if the ice particularly large if you deplete the CEO gas in the mid plane.

327
00:51:32.490 --> 00:51:34.290
Diana Powell: And so that's what I'm showing here on the right.

328
00:51:35.490 --> 00:51:45.870
Diana Powell: So once the initial abundance of SEO gas strong and solid black is depleted in the mid plane I shown in gray. There's a concentration gradient. So this gray line has probably gradient

329
00:51:46.620 --> 00:51:54.570
Diana Powell: Which is then smooths by vertical diffusion. And so this will ultimately lead to a depletion of CEO and the observed upper levels as shown in solid red

330
00:51:55.770 --> 00:52:01.800
Diana Powell: And this is the so called called finger effect which can lead to a large depletion of CO gas and the apprentice.

331
00:52:06.150 --> 00:52:09.930
Diana Powell: And so the particles and gas in the system of all freely as well as vertically

332
00:52:10.830 --> 00:52:26.070
Diana Powell: And so early times gas is depleted fastest in the desk just a bit exterior to the McLean I slide where the disc is called and vertical desta fusion is relatively fast with time CEO gas is increasingly depleted in the outer disk as vertical fusion has time to operate.

333
00:52:27.240 --> 00:52:35.670
Diana Powell: And then enter this interior to them and play nice slide is particles drift in words, until they reach a warm enough region of interest or they released their volatiles content.

334
00:52:37.140 --> 00:52:42.270
Diana Powell: And this causes there to be an increased abundance of SEO gas in the inner desk that can then be created onto the host star.

335
00:52:44.730 --> 00:52:48.360
Diana Powell: Okay, the revenue through one pretty picture before I show you some some final results.

336
00:52:50.130 --> 00:52:53.130
Diana Powell: OK, so I'll quickly walk you through the evolution of SEO and discs.

337
00:52:54.180 --> 00:53:01.740
Diana Powell: An outer disk co gases continually mix down towards the dismiss PLANE, WE'RE efficient ice permission occurs on large particles.

338
00:53:03.300 --> 00:53:06.270
Diana Powell: These large particles drift inwards towards their hosts stars.

339
00:53:07.500 --> 00:53:16.440
Diana Powell: Once the size particles drift to the hotter regions of the desk. They released their volatiles to back into the guest is so interesting cycling and material happens around the Iceland.

340
00:53:17.850 --> 00:53:23.400
Diana Powell: And then there's the enhanced abundance of SEO gas and enter disk that is accreted onto the hosts are over time.

341
00:53:26.820 --> 00:53:34.440
Diana Powell: So we find that agreement between our modeling results and observations. So I'm showing here. The four discs that we model and plots be three.

342
00:53:36.420 --> 00:53:43.620
Diana Powell: And and I'm modeling, we find that this process depends strongly on the fusion, which contributes to the observed periods of CO depletion and different discs.

343
00:53:44.850 --> 00:53:52.740
Diana Powell: Some large flat. Here you can see the amount of absurd depletion and Autodesk depends on the amount of diffusing that has operated in the lifetime of these discs.

344
00:53:54.240 --> 00:54:07.830
Diana Powell: And I will note that this process is also applicable to other volatiles and discs. So the micro physical processes information both regulates the observed abundances of CO gas and is crucial in determining the radio composition of protoplanetary this

345
00:54:10.380 --> 00:54:10.740
Okay.

346
00:54:12.120 --> 00:54:19.500
Diana Powell: So I think my time is up. So I'll conclude by saying that I've talked about understanding some seller atmospheres is in cloud metaphysics.

347
00:54:20.130 --> 00:54:30.990
Diana Powell: And I discussed uncovering fundamental properties of protoplanetary disks using particle aerodynamics and isolation and I hope I've shown you convince you of the following up losing concluding points. Thank you so much.

348
00:54:38.040 --> 00:54:38.700
Ana Bonaca: Wonderful.

349
00:54:40.170 --> 00:54:41.910
Diana Powell: Really like the clapping track what's next.

350
00:54:42.990 --> 00:54:47.310
Ana Bonaca: I have to say this as I first started at the exoplanet

351
00:54:48.360 --> 00:54:55.590
Ana Bonaca: Presentation logs. I thought it was like really nice do okay yeah show our appreciation. Okay.

352
00:54:55.620 --> 00:54:58.710
Morgan Elowe MacLeod: Thank you so much for us. We get to potentially a sitcom right

353
00:55:03.720 --> 00:55:04.650
Diana Powell: To left track for that.

354
00:55:08.400 --> 00:55:09.330
Ana Bonaca: In post processing.

355
00:55:11.880 --> 00:55:13.590
Ana Bonaca: I have so many questions.

356
00:55:15.240 --> 00:55:17.580
Ana Bonaca: Down as as you were going along, but maybe

357
00:55:18.930 --> 00:55:33.420
Ana Bonaca: And by the way, I love the illustrations and you can maybe like just the two, you mentioned that this transition between, like, four, and five. And on this slide on the ice slider. There is some interesting co cycling happening there. So, just wondering

358
00:55:35.160 --> 00:55:46.140
Ana Bonaca: I how important that that transition is and how, how can we go forward to understanding it both I guess operationally and also on the theory side.

359
00:55:47.370 --> 00:55:52.560
Diana Powell: Yeah, so this isn't this wasn't a main focus of this work, although we do find out what other people have found is that

360
00:55:52.800 --> 00:55:58.290
Diana Powell: We confirm what other people have found with similar modeling where when these ice particles drift in past the ice line.

361
00:55:58.530 --> 00:56:07.320
Diana Powell: They released their gas some of that gases then immediately cycled back and actually happens more efficiently in our modeling, because we have this depleted gas exterior the ice line.

362
00:56:08.220 --> 00:56:18.030
Diana Powell: That's quite significantly depleted. Until then, it goes back across Iceland form is more ice. Some of those ice particles drift in but you end up with like that enhancement of ice just exterior to baseline.

363
00:56:18.510 --> 00:56:24.990
Diana Powell: And so people have proposed that that could be really important for forming planets. So people think that's a nice location, the forum.

364
00:56:25.950 --> 00:56:38.730

Diana Powell: giant planets extra ice around and then also observational it. So this is so far not enough, David. David model for the substructure. We see index, but it has been proposed that isolates could lead to the substructure that you see.

365
00:56:39.210 --> 00:56:46.410
Diana Powell: Although I think that's a bit out of favor right now people are mostly thinking minutes but it's good to help other alternatives. Yes.

366
00:56:46.800 --> 00:56:48.450
Ana Bonaca: It's good vacation open mind and

367
00:56:48.960 --> 00:56:49.590
Ana Bonaca: Sounds like

368
00:56:49.650 --> 00:57:01.680
Ana Bonaca: Morgan has been thinking along the same line on this information and CEO depletion and he is wondering whether this can teach us about the turbulent our Christian properties and that this themselves.

369
00:57:02.430 --> 00:57:05.820
Diana Powell: Yeah, so something that's that's really nice. And there's modeling.

370
00:57:06.690 --> 00:57:15.390
Diana Powell: So right now I so basically the main free parameter that the key free free parameter. I have for all the systems is how much mixing is taking place.

371
00:57:15.840 --> 00:57:24.420
Diana Powell: So I printer is that to peaceably like an alpha, this model. So a period like bulk turbulent properties, but it's very sensitive to this parameter like

372
00:57:24.630 --> 00:57:34.380
Morgan Elowe MacLeod: Is there vertical mixing because it seems like vertical mixing is important, but also the radial diffusion is there are they separate or are they linked by the same

373
00:57:35.430 --> 00:57:36.570
Morgan Elowe MacLeod: Alpha kind of

374
00:57:37.140 --> 00:57:49.890

Diana Powell: Yeah. So you can imagine, and maybe like some process that can lead to an ISO tropic turbulence. So that's been proposed. I think for different hydrodynamic instabilities and our modeling we assume that they're both linked by the same alpha, OK.

375
00:57:51.030 --> 00:57:55.650
Diana Powell: So the same alpha operating in both directions. So it's kind of like a bulk how much mixing isn't these discs.

376
00:57:55.860 --> 00:57:59.160
Diana Powell: But what's nice is that that's every parameter that's the one thing I tune

377
00:57:59.340 --> 00:58:06.960
Diana Powell: And all these plots and for all the discs. They lie and the range. The Office that we get out are the kind of offers you could plausibly expect to see in discs.

378
00:58:07.350 --> 00:58:15.900
Diana Powell: So I don't get any crazy high alphas creasing low offers so it seems reasonable. So I do think with more data with more desks actually really with more

379
00:58:15.900 --> 00:58:23.850
Diana Powell: Desk. I would feel comfortable saying that this is a nice probe up the turbulent properties and then hopefully, it could be ruled out or confirmed with some future observations.

380
00:58:24.600 --> 00:58:34.470
Morgan Elowe MacLeod: And there's the thought that that are, that is a I mean maybe this is the case in the modeling, but also sort of in general is to do we think that there should be

381
00:58:35.070 --> 00:58:48.270
Morgan Elowe MacLeod: An alpha that is constant within disk radius, such that, like the mass flux is preserved or or is that not the case in some of these discs because they have like maybe dead spots and stuff like that.

382
00:58:48.990 --> 00:58:51.570
Diana Powell: Yeah, I would say it's a very open question.

383
00:58:51.660 --> 00:58:54.480
Diana Powell: You could definitely imagine. So something that could be

384
00:58:55.350 --> 00:59:02.910
Diana Powell: I'm kind of nice. And this modeling. So right now we don't have great observations of the inner desk either optically thick or we don't have enough resolution, but

385
00:59:03.540 --> 00:59:10.530
Diana Powell: You could imagine if there's lots of depletion in the inner desk, the way that you would get that from this model, you have increased mixing in the interests compared to the outer disk.

386
00:59:10.830 --> 00:59:16.380
Diana Powell: There's some reasons to think that could be true, like maybe you're driving MRI and enter desk. You've dead zones in the outer disk.

387
00:59:17.040 --> 00:59:28.260
Diana Powell: Maybe you accrete by disk wins and that preferentially happens in the inner disk. So you could imagine there being quite a lot of structure to this alpha parameter which we kind of smooth over interesting how much kind of bulk mixing dvd

388
00:59:30.390 --> 00:59:31.440
Morgan Elowe MacLeod: That's really interesting.

389
00:59:33.360 --> 00:59:35.790
Ana Bonaca: So maybe the clothes are

390
00:59:36.930 --> 00:59:39.000
Ana Bonaca: On the topic of clouds.

391
00:59:40.650 --> 00:59:59.760
Ana Bonaca: As it was really nice to see all the different transmission spectra of clouds of different chemistries. And so as wondering like, are those can we will we be able to yeah actually determine the composition of clouds with Jay devil a steam editor you have holidays.

392
01:00:01.110 --> 01:00:02.970
Ana Bonaca: Nice predictions from your work.

393
01:00:04.110 --> 01:00:15.480
Diana Powell: Yeah, so I'm really excited about the prospects. So in particular, the kind of smoking gun for clouds are these broad absorption features and the infrared. You can see them in both of these plots here out past 10 microns.

394
01:00:16.950 --> 01:00:25.350
Diana Powell: So they're kind of complicated. So the broad, which makes them a little bit harder to detect and also they depend sensitively on the size distribution. So you can see that in the top spot here.

395
01:00:25.650 --> 01:00:33.180
Diana Powell: So you have basically the same cloud species, but the size distribution is different. And so the amplitude and shape of this looks different, but basically if you get a broad feature there.

396
01:00:33.570 --> 01:00:41.100
Diana Powell: Then you I think you're quite clear that's particles blocking. It's not something like high atmospheric me molecular weight, which I didn't talk about I'm for giant planets.

397
01:00:41.760 --> 01:00:49.710
Diana Powell: Seems a little bit less likely. But if you do get like a nice like in the bottom part. You see this nice future definitely like silicate clouds.

398
01:00:51.360 --> 01:00:52.110
Diana Powell: I think it's possible.

399
01:00:53.160 --> 01:01:00.300
Diana Powell: There's also prospects of using them to probe atmospheric variability. Like if clouds are going to climate cycles and raining out and you would expect that teacher

400
01:01:00.630 --> 01:01:09.420
Diana Powell: To maybe have significant amplitude variations which is also exciting. So yeah, I think what James up. There's lots of awesome prospects, particularly for giant planets, but maybe even for small ones.

401
01:01:11.160 --> 01:01:11.460
Diana Powell: Definitely

402
01:01:14.700 --> 01:01:16.530
Ana Bonaca: I can imagine that. Yeah, that that plays a

403
01:01:17.670 --> 01:01:18.750
Ana Bonaca: Huge role on

404

01:01:19.950 --> 01:01:22.020
Ana Bonaca: Your whole planets and ability and

405
01:01:24.060 --> 01:01:30.030
Morgan Elowe MacLeod: It's kind of amazing to start thinking about monitoring the weather on an exoplanet oh

406
01:01:30.930 --> 01:01:31.230
Diana Powell: You got

407
01:01:31.710 --> 01:01:33.000
Morgan Elowe MacLeod: A little bit late, right, but

408
01:01:35.580 --> 01:01:37.620
Diana Powell: That's true. A little, just a few years deludes

409
01:01:41.520 --> 01:01:48.990
Ana Bonaca: Thank you so much, you have more questions for I think both of you on our Slack channel, so please stick around.

410
01:01:50.070 --> 01:01:56.280
Ana Bonaca: Thank you all for joining us. A faithful. We'll see you next week. And thanks to our speakers again.

411
01:01:56.400 --> 01:01:59.340
Diana Powell: Thank you. Thank you for having us.

412
01:02:00.180 --> 01:02:01.050
Jennifer Andrews: For having me.

413
01:02:04.080 --> 01:02:04.950
Thanks for coming.