

WEBVTT

1

00:00:00.000 --> 00:00:00.690

Morgan Elowe MacLeod: cloud.

2

00:00:02.730 --> 00:00:04.020

Morgan Elowe MacLeod: Okay wonderful.

3

00:00:05.279 --> 00:00:15.150

Morgan Elowe MacLeod: Thank you everyone for being here, thank you to our speaker today we're really excited to start our third colloquium of this semester.

4

00:00:16.170 --> 00:00:34.980

Morgan Elowe MacLeod: Today we have our own classes Silva and where we were just laughing before the call about how strange it is to all be collectively, you know after the CFA, but most of us aren't spending much time there these days.

5

00:00:36.510 --> 00:00:41.970

Morgan Elowe MacLeod: notes and spray exactly exactly.

6

00:00:44.340 --> 00:00:46.620

Morgan Elowe MacLeod: And so.

7

00:00:48.870 --> 00:00:51.180

Morgan Elowe MacLeod: Anyway, Clara Clara is.

8

00:00:52.620 --> 00:01:00.630

Morgan Elowe MacLeod: A 51 peg be fellow at the CFA previously she spent time at.

9

00:01:00.660 --> 00:01:07.170

Morgan Elowe MacLeod: MIT and before that did her PhD and.

10

00:01:08.340 --> 00:01:21.090

Morgan Elowe MacLeod: sort of the intersection of chemistry and astrophysics at ucl in London so we're delighted to get to hear from Kleiner today, and I think many of us are going to learn a lot.

11

00:01:22.110 --> 00:01:34.470

Morgan Elowe MacLeod: And then we have about half of our time today for discussion, so if at any point as we go, you have questions if you could please private message me Morgan.

12

00:01:35.790 --> 00:01:51.720

Morgan Elowe MacLeod: A few words about the topic of your question, so it doesn't have to be the entirety of your question, but just a few words, then that will all sort of start a running queue and i'll call on you to flesh out your question and and we can have a conversation from that.

13

00:01:54.510 --> 00:01:59.520

Morgan Elowe MacLeod: So I think that is all of the logistics so without further ado.

14

00:02:00.630 --> 00:02:02.190

Morgan Elowe MacLeod: we're delighted to have you today.

15

00:02:03.270 --> 00:02:04.320

Clara Sousa-Silva: Thank you, Morgan okay.

16

00:02:04.380 --> 00:02:05.940

Clara Sousa-Silva: let's try this a third time.

17

00:02:08.100 --> 00:02:09.780

Clara Sousa-Silva: Can you see my title screen.

18

00:02:10.830 --> 00:02:11.910

Clara Sousa-Silva: Can you see only my.

19

00:02:11.910 --> 00:02:16.440

Morgan Elowe MacLeod: titles for you, we see the presenter screen okay.

20

00:02:16.470 --> 00:02:17.430

Clara Sousa-Silva: What about now.

21

00:02:20.760 --> 00:02:23.520

Morgan Elowe MacLeod: it's frozen for me okay.

22

00:02:23.640 --> 00:02:25.110

Clara Sousa-Silva: let's try a fourth time.

23

00:02:33.510 --> 00:02:34.650

Clara Sousa-Silva: Can you see the title screen.

24

00:02:35.190 --> 00:02:36.570

Morgan Elowe MacLeod: Now we see the presenter screen.

25

00:02:38.100 --> 00:02:38.730

Clara Sousa-Silva: What about now.

26

00:02:38.970 --> 00:02:39.990

Morgan Elowe MacLeod: Yes, now, you see it.

27

00:02:40.920 --> 00:02:42.360

Clara Sousa-Silva: Okay we're in.

28

00:02:43.230 --> 00:02:44.460

Morgan Elowe MacLeod: Exactly Thank you.

29

00:02:45.000 --> 00:02:45.690

Clara Sousa-Silva: All right.

30

00:02:46.590 --> 00:02:48.210

Morgan Elowe MacLeod: hi everyone and.

31

00:02:48.480 --> 00:03:02.940

Clara Sousa-Silva: Thank you for being here and all that Morgan said was true and so i'll talk a little bit about my work which all of it, no matter how kind of weird or normal revolves around molecular spectroscopy and specifically.

32

00:03:04.350 --> 00:03:21.390

Clara Sousa-Silva: I look at mostly trembley extremely respectful and fundamental research, but it does have kind of endless applications, some of which are less respectful and, like my favorite which is looking for alien life so i'll try to touch on all those aspects and here today.

33

00:03:23.850 --> 00:03:33.990

Clara Sousa-Silva: So I sometimes like to reverse my work and I imagine what it would be like to be an alien astronomy, on the other side of the galaxy Morgan, can you confirm that you can see the Milky Way excellent.

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00:03:34.560 --> 00:03:40.890

Clara Sousa-Silva: And, and I imagine that, if they pointed their telescopes to their son, and this is exactly what they would see.

35

00:03:42.210 --> 00:03:50.850

Clara Sousa-Silva: That would see our sun spectrum and they would be able to use their universal knowledge of spectroscopy that they would get from their own quantum master chemists like myself.

36

00:03:51.270 --> 00:04:00.060

Clara Sousa-Silva: and be able to figure out exactly which molecules and atoms were causing these absorption lines that you see on the screen and use this information figure out the composition of the sun.

37

00:04:01.110 --> 00:04:05.700

Clara Sousa-Silva: And that's because every atom every molecule has a unique spectroscopic fingerprint.

38

00:04:06.450 --> 00:04:12.180

Clara Sousa-Silva: And if these alien astronomers had just slightly better technologies and we have now and we're well aligned.

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00:04:12.630 --> 00:04:21.060

Clara Sousa-Silva: They would notice that, every year, a few new absorption lines would show up in the sun spectrum and then disappear, and then a year later appear again and then disappear.

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00:04:21.510 --> 00:04:27.990

Clara Sousa-Silva: And these will be due to the molecules in our earth's atmosphere and they will be able to interpret these new absorption lines and.

41

00:04:28.380 --> 00:04:43.470

Clara Sousa-Silva: learn a lot about us, you can think of our atmosphere and it's subsequent spectrum as a planet size message communicating to the galaxy that we have oceans and forests and varied ecosystems with rich life cycles and also that we pollute a lot.

42

00:04:44.910 --> 00:04:53.130

Clara Sousa-Silva: And we can do the same to them and that's what i'm working on it's fascinating to me that sometime in the very near future.

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00:04:53.460 --> 00:05:02.670

Clara Sousa-Silva: Questions as ambitious as does that planet host life will likely be answered by understanding something as small and fundamental as the quantum behavior molecules.

44

00:05:03.420 --> 00:05:09.870

Clara Sousa-Silva: But this behavior isn't particularly simple each molecule has their own spectrum which look roughly like these ones.

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00:05:10.380 --> 00:05:19.080

Clara Sousa-Silva: describing how each molecule interacts with light and if we want to detect any of these molecules and astronomical spectra, we need to know what its individual spectral looks like.

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00:05:19.920 --> 00:05:26.370

Clara Sousa-Silva: And if we want to interpret astronomical spectra correctly and completely Ideally, we want good quality spectra.

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00:05:27.060 --> 00:05:35.250

Clara Sousa-Silva: To start with, we definitely want accurate spectra so way accurate, I mean we know the correct location and strength of each relevant special feature.

48

00:05:35.520 --> 00:05:41.610

Clara Sousa-Silva: For example, here in black I my theoretical calculations of the fascia and spectrum that I did with the small group in London, during my PhD.

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00:05:42.180 --> 00:05:48.180

Clara Sousa-Silva: The mirrored in red are the experimental measurements, as provided by the excellent high tron database right here at the CFA.

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00:05:48.750 --> 00:05:55.020

Clara Sousa-Silva: who have excellent excellent spectrum measured with miniscule uncertainties and, in this case, in agreement with my calculations.

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00:05:55.470 --> 00:06:02.340

Clara Sousa-Silva: So by accurate I also mean that theoretical simulations agree well with experiment, but good spectra as much as accurate.

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00:06:02.940 --> 00:06:11.550

Clara Sousa-Silva: spectral quality also depends on coverage, for example, this is hydrogen peroxide and in blue you see all of the current experimental measurements for the molecule.

53

00:06:12.360 --> 00:06:18.960

Clara Sousa-Silva: The features, you see here are very accurate, but that doesn't guarantee coverage and other wavelengths so the molecule may be sexually active.

54

00:06:19.500 --> 00:06:29.400

Clara Sousa-Silva: As you can see here and read theoretical calculations, also for maximum all tell us a hydrogen peroxide actually absorbs a much wider range of wavelengths than the current experimental data would have you believe.

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00:06:30.210 --> 00:06:38.610

Clara Sousa-Silva: In case you're wondering this isn't a hydrogen peroxide problem hundreds of molecules have only partial spectrum even really important ones like water.

56

00:06:39.300 --> 00:06:53.040

Clara Sousa-Silva: For example here on red and blue are two different but widely use a few assumptions of the spectral behavioral of water and they agreed that water was simply not sexually active beyond about 208 nanometers.

57

00:06:53.700 --> 00:07:00.120

Clara Sousa-Silva: In fact, almost every atmospheric model that includes Walter in this wavelength region is using one of these two prescriptions.

58

00:07:01.080 --> 00:07:13.350

Clara Sousa-Silva: The first thing to note here is that these blue lines aren't even measurements they're just a very reasonable assumption of the water spectrum, as it approaches association, but what I want to note is that these aren't necessarily showing the full picture.

59

00:07:14.370 --> 00:07:24.150

Clara Sousa-Silva: In fact, my collaborators and I recently found that well beyond 208 nanometers waters absorption is weak, but it isn't zero it just hadn't be measured beyond that point.

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00:07:24.660 --> 00:07:38.370

Clara Sousa-Silva: You can see our measurements and pink and purple and black my most conservative theoretical estimate these new special features of water are far too faint to be used to actually detect water directly but they're not inconsequential.

61

00:07:39.510 --> 00:07:51.390

Clara Sousa-Silva: What we found was when these new Water spectral were included in photochemical models of planets with a biotic anoxic atmosphere so roughly an angle analogous to earlier Thor Mars or Venus.

62

00:07:52.050 --> 00:07:58.740

Clara Sousa-Silva: The predictive production of voice radicals goes up, and this has drastic consequences for the composition of the atmosphere.

63

00:07:59.400 --> 00:08:09.990

Clara Sousa-Silva: Specifically, the predicted abundances of car monoxide oxygen and, in some cases methane and hydrogen went down by many orders of magnitude so spectral coverage is really important.

64

00:08:11.010 --> 00:08:16.170

Clara Sousa-Silva: A good spectra isn't just accurate and comprehensive it's also complete.

65

00:08:16.680 --> 00:08:24.300

Clara Sousa-Silva: And by completeness What I mean is that you know how many features of a given molecule you need to correctly simulated and sometimes you need loads.

66

00:08:24.780 --> 00:08:29.370

Clara Sousa-Silva: For example, here in white do you see the observational spectrum, from a meeting rich browned off.

67

00:08:29.970 --> 00:08:39.600

Clara Sousa-Silva: using an experimental spectrum with 350,000 extremely accurately measured features across this whole range some of the spectrum could be quite well replicated.

68

00:08:39.960 --> 00:08:51.990

Clara Sousa-Silva: Some, but not all, despite as many features, in fact, in this case, these data could only be replicated with a much more complete line less for methane calculated theoretically with 10 billion features, also by xml.

69

00:08:53.760 --> 00:09:00.540

Clara Sousa-Silva: So i've highlighted a few special concerns about a few molecules but, as you can imagine, there are many, many more molecules to worry about.

70

00:09:01.200 --> 00:09:10.740

Clara Sousa-Silva: And even with this new, improved understanding of these molecules spectra we're only just beginning to understand what it would mean to actually find them and zopa atmosphere.

71

00:09:11.610 --> 00:09:18.060

Clara Sousa-Silva: Take for example philosophy, when I first started working on phosphenes it was really only known for two things one.

72

00:09:18.420 --> 00:09:24.450

Clara Sousa-Silva: As a marker for violent storms on Jupiter and Saturn so phosgene is detected in the upper layers of these planets but.

73

00:09:24.780 --> 00:09:33.030

Clara Sousa-Silva: It is a tiny bit surprising because the temperature and hydrogen pressure there are far too low for the formation of phosphenes to meet them are dynamically favorite.

74

00:09:33.630 --> 00:09:39.600

Clara Sousa-Silva: But what happens is fasting after after being happily formed in the hellish depths of these planets.

75

00:09:40.050 --> 00:09:46.650

Clara Sousa-Silva: it's aggressively dragged to the top by strong currents surviving too much larger concentrations in a predictable local thermal equilibrium.

76

00:09:47.580 --> 00:09:55.170

Clara Sousa-Silva: But on rocky planets like the earth we don't have those extreme environments, like the depths of Jupiter so phosphenes is rarely made spontaneously.

77

00:09:55.770 --> 00:10:04.710

Clara Sousa-Silva: on earth phosphenes mostly notorious for being a lethal and foul smelling molecule, which brings me to the second thing fostering is known for.

78

00:10:05.520 --> 00:10:19.380

Clara Sousa-Silva: Fostering interacts fatally with oxygen metabolism so it's a really effective killer and for this reason, we often use phosphenes a pesticide on earth, and sadly also for this reason we have used it as a chemical weapon for over 100 years.

79

00:10:20.550 --> 00:10:31.200

Clara Sousa-Silva: So far, seen is mostly awful and deadly but what I found was that it has one very important characteristic for life that doesn't rely on oxygen phosphenes perfectly safe.

80

00:10:31.890 --> 00:10:41.850

Clara Sousa-Silva: In fact, on earth, I reviewed all the reports of fostering detections and found that it's produced on all manners of anoxic ecosystems so places like sewage marshlands or.

81

00:10:42.270 --> 00:10:48.750

Clara Sousa-Silva: Like settlements, and also the intestinal tract of fish and babies and actually the guts of most animals.

82

00:10:49.380 --> 00:10:55.710

Clara Sousa-Silva: So I wanted to find out could oxygen poor planets have detectable fostering rich biospheres.

83

00:10:56.490 --> 00:11:03.240

Clara Sousa-Silva: to explore the possibility, myself and my team use multiple detect ability metrics and photochemical and radiative transfer codes.

84

00:11:03.900 --> 00:11:12.540

Clara Sousa-Silva: Basically, to figure out a could for phosphenes survive in a variety of hypothetical extreme for planets be detectable in the near future.

85

00:11:13.320 --> 00:11:25.560

Clara Sousa-Silva: and be distinguishable from other molecules and my calculations do show the fostering has a beautiful and distinctive spectrums in here and back that does set it apart from other molecules senior in color.

86

00:11:26.100 --> 00:11:43.110

Clara Sousa-Silva: And we found that with J w St we could detect fostering oxygen for planets even around active em dwarfs and bolts transmission and emission so with near spec and miri respectively, and with completely reasonable false in production rates so comparable to those found.

87

00:11:44.190 --> 00:11:51.750

Clara Sousa-Silva: Well, well below actually those found above the strongest force in producing anaerobic systems on earth so places like sewage plants or penguin colonies.

88

00:11:52.860 --> 00:12:05.280

Clara Sousa-Silva: Now for some like stars, we were trying to harder, but still possible to detect fall screen on only a few scenarios, namely hydrogen rich planets and only if they really like producing phosphenes so you know, a sewage planet and and test them planet.

89

00:12:06.990 --> 00:12:13.050

Clara Sousa-Silva: And we did these calculations with Jacob listy in mind, so we could focus on the near future, but lots of other.

90

00:12:13.380 --> 00:12:24.360

Clara Sousa-Silva: Future missions, like our reality PSI Darwin award 30 meter class around telescopes will certainly be able to characterize atmospheres of planets and wavelengths for phosphenes active.

91

00:12:25.050 --> 00:12:27.690

Clara Sousa-Silva: And this makes us feel really promising as a bio signature.

92

00:12:28.350 --> 00:12:38.610

Clara Sousa-Silva: Or what makes fasting really appealing is that it seems to have no significant false positives for life as long as it's fine on rocky temperate planets so definitely not a sign of life on Jupiter.

93

00:12:39.450 --> 00:12:47.880

Clara Sousa-Silva: And to figure this out, we looked first at standard chemical processes and we found that in all cases, the formation of phosphenes was highly thermodynamics linda's favorite.

94

00:12:48.450 --> 00:12:55.590

Clara Sousa-Silva: So, then, we looked at lightning and volcanism and meet tools and found that even in the most favorable atmospheric scenarios, so those that are highly reduced.

95

00:12:56.130 --> 00:13:09.270

Clara Sousa-Silva: Only a notable fraction of phosphorus could turn fostering and always many orders of magnitude below anything we could attacked so that point we did look into increasingly more plausible scenarios and none delivered any substantial false positives for philosophy.

96

00:13:10.530 --> 00:13:19.920

Clara Sousa-Silva: So the signing in mind, I wrote this article, with a conclusion that read any detectable amounts of phosphenes on a rocky planet cannot be explained without life.

97

00:13:20.430 --> 00:13:31.320

Clara Sousa-Silva: And when I first submitted this paper, I thought this was a pretty cool conclusion but it wasn't controversial at all, it was

just me describing a totally theoretical hypothetical situation, no one was really concerned about.

98

00:13:32.250 --> 00:13:44.910

Clara Sousa-Silva: I was imagining this sort of distant planet and anoxic tropical paradise with a rich bias here producing tremendous amounts of phosphenes that we might one day, hopefully, when i'm still alive, be able to observe.

99

00:13:45.750 --> 00:13:51.360

Clara Sousa-Silva: And you might not know that philosophy turned out to be a little more exciting than I had initially envisaged.

100

00:13:51.900 --> 00:14:01.470

Clara Sousa-Silva: Because a few months after I submitted this paper and astronomer Cardiff called Jane grieves reached out to me asking for help interpreting JC empty observation seeing here in white.

101

00:14:01.920 --> 00:14:09.990

Clara Sousa-Silva: And later, a follow up with Alma shown here in orange that seemed to indicate the fostering might be present in the clouds of Venus the only potential.

102

00:14:10.530 --> 00:14:19.680

Clara Sousa-Silva: potentially have to a location on the planet Jane knew this was strange, but she needed a phosgene expert to know how strange and that's where I came in and how collaboration again.

103

00:14:20.820 --> 00:14:28.050

Clara Sousa-Silva: Now the notion that fall seen a molecule that I had claimed was a very promising bio signature might be president Venus is, of course.

104

00:14:28.500 --> 00:14:44.010

Clara Sousa-Silva: very exciting and the press thought so too, but before we jump on life as an explanation I should point out that they're still very much well there's a lot about Venus we don't understand, and all we really know is that there's something weird happening on Venus.

105

00:14:45.240 --> 00:14:53.040

Morgan Elowe MacLeod: interrupted the question so, which is the Venus spectrum I a couple people were asking online.

106

00:14:53.760 --> 00:14:56.310

Clara Sousa-Silva: Oh so Both of these are specular from.

107

00:14:56.520 --> 00:15:00.660

Morgan Elowe MacLeod: The the lower panel or the upper.

108

00:15:02.040 --> 00:15:10.050

Morgan Elowe MacLeod: Our Pal it's possible this Green froze we're seeing the into an hd with different parts per million.

109

00:15:11.190 --> 00:15:12.540

Clara Sousa-Silva: into an H two.

110

00:15:15.360 --> 00:15:19.320

Clara Sousa-Silva: O into an H two O you're seeing a telescope.

111

00:15:19.830 --> 00:15:21.270

Morgan Elowe MacLeod: Know we're seeing.

112

00:15:22.980 --> 00:15:23.160

Morgan Elowe MacLeod: The.

113

00:15:23.940 --> 00:15:25.950

Ana Bonaca: This is the gw St prediction.

114

00:15:25.980 --> 00:15:26.610

Morgan Elowe MacLeod: that's right.

115

00:15:27.180 --> 00:15:30.120

Clara Sousa-Silva: Oh, how straight to miss a frozen at that point and.

116

00:15:31.620 --> 00:15:35.400

Clara Sousa-Silva: Let me stop and start the sharing again sorry.

117

00:15:36.450 --> 00:15:37.710

Clara Sousa-Silva: So you saw this.

118

00:15:38.940 --> 00:15:39.480

Morgan Elowe MacLeod: A.

119

00:15:39.960 --> 00:15:41.370

Ana Bonaca: high price, even before that.

120

00:15:41.730 --> 00:15:42.630

Morgan Elowe MacLeod: We we didn't.

121

00:15:43.080 --> 00:15:44.220

Ana Bonaca: realize before.

122

00:15:45.330 --> 00:15:50.070

Clara Sousa-Silva: Oh i'm sorry, so you were just listening to my voice God, I must have been tough.

123

00:15:50.400 --> 00:15:57.330

Morgan Elowe MacLeod: No, I mean it, it may be, what you're talking about, but I didn't realize there was other slide.

124

00:15:57.360 --> 00:15:58.350

Clara Sousa-Silva: You see.

125

00:15:58.650 --> 00:16:00.840

Morgan Elowe MacLeod: We see the presenter slide again.

126

00:16:00.960 --> 00:16:03.240

Clara Sousa-Silva: that's Okay, what about now.

127

00:16:05.400 --> 00:16:08.190

Morgan Elowe MacLeod: It didn't change for me how.

128

00:16:08.220 --> 00:16:10.680

Clara Sousa-Silva: peculiar and.

129

00:16:11.730 --> 00:16:14.130

Clara Sousa-Silva: let's try directly with a desktop.

130

00:16:16.590 --> 00:16:19.110

Clara Sousa-Silva: Okay, do you see my presenter notes or the slide.

131

00:16:19.560 --> 00:16:20.520

Morgan Elowe MacLeod: presenter notes.

132

00:16:21.210 --> 00:16:22.170

Clara Sousa-Silva: Because now the slide.

133

00:16:22.230 --> 00:16:22.680

Morgan Elowe MacLeod: yeah.

134

00:16:22.830 --> 00:16:24.510

Clara Sousa-Silva: yeah and now do you see Jay diversity.

135

00:16:24.540 --> 00:16:37.260

Clara Sousa-Silva: We do excellent Okay, where were you okay gentlemen Steve great telescope we could probably use a different philosophy false positives I was just explaining what you're seeing now no false positives yay.

136

00:16:38.790 --> 00:16:47.280

Clara Sousa-Silva: phosphenes great bio signature, these were this was my margin planet, and these were the arm and you see him to character.

137

00:16:47.280 --> 00:16:57.750

Clara Sousa-Silva: awesome okay now, it makes sense, seeing here in white and seeing here in orange respectively, so what was that Oh yes, I was saying something weird is happening on Venus.

138

00:16:58.740 --> 00:17:08.370

Clara Sousa-Silva: But we don't know what it is and to figure that out, there are many next steps, and specifically currently there's a lot of controversy surrounding this discovery.

139

00:17:09.090 --> 00:17:20.400

Clara Sousa-Silva: And i'm happy to discuss this here, to some extent, where I can but, ultimately, what we need to do is address the primary uncertainties of this discovery, namely is a snake, the signal real.

140

00:17:20.850 --> 00:17:30.420

Clara Sousa-Silva: If it is, is a fasting and if it is what's making it and to try to answer these questions, I am trying to get more data by looking at Venus in the infrared.

141

00:17:30.990 --> 00:17:39.630

Clara Sousa-Silva: And as we learn more about Venus i'm hoping we can get more better models that can actually help us make sense of exactly what is going on on Venus.

142

00:17:40.170 --> 00:17:50.940

Clara Sousa-Silva: But to make the most of both models and observations we need better spectroscopic data that can not just described phosphenes

but every other atmospheric component of Venus and how they interact with one another.

143

00:17:51.690 --> 00:17:57.210

Clara Sousa-Silva: This spectroscopic toolkit is vital for us to understand what's happening on Venus and I am working on it, but.

144

00:17:58.920 --> 00:18:09.360

Clara Sousa-Silva: What I want to highlight here is how a virtually unknown and really quite unusual and disgusting molecule became such an important piece of the puzzle in the search for life beyond Earth.

145

00:18:09.720 --> 00:18:16.140

Clara Sousa-Silva: And fasting is just one molecule and Venus is just one planet, even if it turns out that, indeed, we have found fostering on Venus.

146

00:18:16.500 --> 00:18:26.400

Clara Sousa-Silva: This won't be the last time that we find a potential bio signature on a planet beyond ours, so the question is, will we be better prepared to interpret such a discovery next time.

147

00:18:27.390 --> 00:18:33.810

Clara Sousa-Silva: And that's where I'm working towards. Take, for example, the slightly more popular and palatable bio signatures.

148

00:18:34.380 --> 00:18:41.610

Clara Sousa-Silva: These are molecules that life we find pleasant. Like methane and carbon dioxide produced in large quantities by life.

149

00:18:42.030 --> 00:18:50.370

Clara Sousa-Silva: But also molecules like hydrogen cyanide which I'm particularly popular now but we're likely crucial as a building block of life, so a good pre-bio signature.

150

00:18:51.090 --> 00:18:54.750

Clara Sousa-Silva: Now we know these gases and we can and should look for them and exoplanet atmospheres.

151

00:18:55.440 --> 00:19:00.540

Clara Sousa-Silva: But none of these molecules on their own wouldn't necessarily indicate life as they all have false positives.

152

00:19:01.050 --> 00:19:08.040

Clara Sousa-Silva: And this is true for most of the atmospheric gases that life loves and it isn't a cruel astro biological coincidence.

153

00:19:08.730 --> 00:19:14.730

Clara Sousa-Silva: This false positive problem happens because the chemical potential energy gradients that life likes to exploit.

154

00:19:15.150 --> 00:19:28.530

Clara Sousa-Silva: Also easily exploited by geochemical processes, so these molecules are great I love them but thermodynamic the speaking they're easy to make and so detection of these molecules and isolation would never necessarily indicate life.

155

00:19:29.430 --> 00:19:45.810

Clara Sousa-Silva: And the main solution to this false positive problem is to carefully consider context, for example, oxygen on its own, we not be a good bio signature putting the exact context of our planet, our son and the other components of our atmosphere oxygen is a wonderful bio signature.

156

00:19:46.860 --> 00:19:50.790

Clara Sousa-Silva: And the same is true for most of and gases we usually considered in the search for life.

157

00:19:51.300 --> 00:19:58.350

Clara Sousa-Silva: These molecules are only good bio signatures if they can be attributed to life after an investigation of the false positive scenarios.

158

00:19:58.620 --> 00:20:11.700

Clara Sousa-Silva: which requires not just an understanding of the stellar and planetary environment but crucially the detection of other potentially much less abundant atmospheric gases that can provide a chemical context to the discovery.

159

00:20:12.630 --> 00:20:23.400

Clara Sousa-Silva: And how many molecules could form this context well my old group at MIT tried to come up with exactly this list of all possible gases that could be produced by life and contribute to an atmospheric spectrum.

160

00:20:23.940 --> 00:20:34.170

Clara Sousa-Silva: And that list contains 16,367 molecules now most of these molecules would likely be present in tiny quantities in any atmospheres they find themselves in.

161

00:20:34.830 --> 00:20:40.230

Clara Sousa-Silva: But they are presence could give us vital clues to interpret their environment and potentially any life within it.

162

00:20:40.800 --> 00:20:51.300

Clara Sousa-Silva: So the very least, we should be able to detect them, but for that we need their spectra and, sadly, out of those thousands of molecules we only have a rough idea of a few hundred of them look like.

163

00:20:51.690 --> 00:21:01.560

Clara Sousa-Silva: And we only have good spectra for a few dozen of them, and that means we only have spectrum of any quality for less than 4% of possible atmospheric gases.

164

00:21:02.310 --> 00:21:07.500

Clara Sousa-Silva: For all the other molecules we have no spectral data at all, which means no hope of remotely detecting them.

165

00:21:08.280 --> 00:21:19.500

Clara Sousa-Silva: And you might wonder why that is, can we just kind of measure them and we can we can record these in the lab, but these experiments are expensive they're often dangerous there's sometimes altogether impossible.

166

00:21:20.100 --> 00:21:25.380

Clara Sousa-Silva: And we would always be restricted by the instrumental limitations of these measurements, as you saw earlier with hydrogen peroxide.

167

00:21:26.430 --> 00:21:32.850

Clara Sousa-Silva: The alternative is to simulate the spectra theoretically and that's what I did for my PhD but it's also not trivial.

168

00:21:33.660 --> 00:21:46.230

Clara Sousa-Silva: I won't go into the details of this here, but the general overview is that to get a molecule spectra you first I first study the unique structure and electrical distribution of any molecule and use that to solve the sugar equation.

169

00:21:46.980 --> 00:21:53.730

Clara Sousa-Silva: First of the motion of electrons and then the motion of the new clay, and that gives me a list of energy levels and a multiple can occupy.

170

00:21:54.420 --> 00:22:05.280

Clara Sousa-Silva: But I can also map the distribution emotion of the electrons also unique for each molecule and use this to figure out how likely transitions are to occur between pairs of energy levels.

171

00:22:06.390 --> 00:22:15.690

Clara Sousa-Silva: This can provide me with a semi coefficients which can turn into intensities so now with transition frequencies and strengths, I can simulate the full spectrum for the molecule.

172

00:22:16.830 --> 00:22:24.330

Clara Sousa-Silva: But these calculations are really hard part of the issue is that for each type of molecular excitation and they're usually millions of them.

173

00:22:24.600 --> 00:22:32.580

Clara Sousa-Silva: So, having the shorter you equation relies on diagnosing enormous matrices, and this is a process that to the largest extent cannot be parallelized or interrupted.

174

00:22:33.210 --> 00:22:38.670

Clara Sousa-Silva: So to theoretically obtained spectrum takes years of work for a molecule and enormous computing power.

175

00:22:39.360 --> 00:22:49.680

Clara Sousa-Silva: Even a small molecule only three or four items will take at least a couple of million cpu hours and we usually have to assign each molecule to a graduate student to focus on for the entire duration of the PhD.

176

00:22:50.790 --> 00:23:03.090

Clara Sousa-Silva: Take philosophy we know it pretty well but that's partially because I spent a large chunk of my 20 simulating it spectrum and associated properties and I would love to repeat this for all the other molecules but.

177

00:23:03.780 --> 00:23:11.610

Clara Sousa-Silva: Just one person, and to do fall seen a single molecule it took a lot of sweat a lot of tears, a lot of computer effort and four years of my life.

178

00:23:12.090 --> 00:23:19.800

Clara Sousa-Silva: Which means if I was going to tackle those thousands of molecules of the same rate take me well over 60,000 years, which is too long.

179

00:23:20.490 --> 00:23:26.370

Clara Sousa-Silva: And I came to this realization a few years ago, when I was writing my PhD well that's now five years ago.

180

00:23:26.910 --> 00:23:33.930

Clara Sousa-Silva: But, at the time I was also the head of education for the twinkle space mission, a tiny space mission that hasn't even launched.

181

00:23:34.590 --> 00:23:43.620

Clara Sousa-Silva: But I found it and I ran edgy twinkle through which I delivered all the educational programs, so the mission, and I was doing this, while I was also training as a high school teacher in the London School.

182

00:23:44.460 --> 00:23:51.000

Clara Sousa-Silva: I noticed that whenever my research was mentioned in the classroom the students and I would get into really interesting discussions, so I thought.

183

00:23:51.360 --> 00:23:58.590

Clara Sousa-Silva: What if I wasn't working and all those molecules alone, so I created a new program called orbits or original research by young twinkle students.

184

00:23:58.980 --> 00:24:04.410

Clara Sousa-Silva: And recruited 15 of my own kids to research molecules of me and three junior scientists who agreed to help.

185

00:24:05.130 --> 00:24:18.780

Clara Sousa-Silva: And this is the first cohort of students, which I split into three groups each dedicated to studying the spectrum of a molecule crucial for understanding exoplanets and their hosts stars, so this is team titanium oxide team acetylene anti methane.

186

00:24:19.620 --> 00:24:28.140

Clara Sousa-Silva: Now these amazing kids learn astrophysics quantum chemistry programming scientific writing and performed original research on these three molecules.

187

00:24:28.560 --> 00:24:33.810

Clara Sousa-Silva: They went from being my high school students to my scientific collaborators and co authors on multiple papers.

188

00:24:34.770 --> 00:24:39.570

Clara Sousa-Silva: The students, you see here then became mentors for next year, students and those the year after and so on.

189

00:24:40.140 --> 00:24:50.880

Clara Sousa-Silva: I hired someone to replace me when I left the UK, so the programs continue without me and since 2018 more than 100 school kids that become published authors of scientific papers through the orbits Program.

190

00:24:53.190 --> 00:25:00.990

Clara Sousa-Silva: let's continue this sort of work thanks Center in the US, I became the director for the Harvard MIT science, research mentoring Program.

191

00:25:01.320 --> 00:25:15.390

Clara Sousa-Silva: In it myself and a small admin team recruit a few junior scientists so postdocs and PhD students and we help them adapt the current astrophysics projects to benefit from student collaborations and then hire and train and pay a salary to.

192

00:25:16.410 --> 00:25:26.280

Clara Sousa-Silva: Local high school students and assignment to mentors and they perform original research through the academic year at the end of the program we have a symposium and i'm hoping you'll all attended this year.

193

00:25:27.450 --> 00:25:37.080

Clara Sousa-Silva: and working with these kids has made me feel that it isn't just me anymore by training and supporting students were able to work on obtaining the molecular fingerprint for several new molecules.

194

00:25:37.560 --> 00:25:41.850

Clara Sousa-Silva: Putting a tiny dent in that list of thousands of potential wise signatures there's still need spectrum.

195

00:25:42.540 --> 00:25:52.650

Clara Sousa-Silva: In the meantime, I calculate that if everyone i've trained joins the effort to obtain the spectra we could reduce those 60,000 years so much more reasonable two decades.

196

00:25:52.980 --> 00:26:00.120

Clara Sousa-Silva: Which is encouraging it just isn't enough for example Jadot Steve will start providing astronomical data in a couple of years fingers crossed.

197

00:26:00.660 --> 00:26:14.280

Clara Sousa-Silva: and, ideally, by then, all of this fundamental spectra should be ready and tested and integrated into atmospheric models otherwise database to provide us with incredible data, but from which our insights will be limited, we need these data quickly but.

198

00:26:15.480 --> 00:26:20.070

Clara Sousa-Silva: Currently measuring or simulating all the necessary spectrum time as an impossible problem.

199

00:26:20.910 --> 00:26:26.400

Clara Sousa-Silva: Which is why I created rascal or rapid approximate spectral calculations for all.

200

00:26:26.910 --> 00:26:33.840

Clara Sousa-Silva: to simulate approximate spectra for those thousands of molecules using a crafty combination of computational organic and quantum chemistry.

201

00:26:34.800 --> 00:26:42.720

Clara Sousa-Silva: The first iteration of rascal works by identifying which groups of atoms and bonds nonis functional groups from active features within a molecule.

202

00:26:43.290 --> 00:26:50.520

Clara Sousa-Silva: So, for example, every ketone with these atoms have as a feature around here and every allocate with a triple bond carbon has a feature in this region.

203

00:26:50.970 --> 00:26:58.410

Clara Sousa-Silva: And the same applies to literally hundreds of functional groups which my team, and I have spent years collecting and assessing and coding into rascal.

204

00:26:59.640 --> 00:27:11.670

Clara Sousa-Silva: We wrote some code using chemo informatics modules that identifies each sexually active functional group within a molecule and then I use that to puzzle together a molecule skeleton spectrum.

205

00:27:12.480 --> 00:27:19.560

Clara Sousa-Silva: For example, take them ethel sulfide on earth at the volatiles produce in large quantities by rb so quite a cool way a signature already.

206

00:27:20.400 --> 00:27:31.920

Clara Sousa-Silva: And rascal stars by recognizing that in this time methyl the central saw the central sulfur atom there's nothing for this molecule spectrum and it's the hydrogen and carbon functional groups that do most of the spectral work.

207

00:27:32.520 --> 00:27:42.270

Clara Sousa-Silva: With this information rascal predicts the approximate position and relative intensities of these molecules features and it does so correctly, as you can see here by comparison with a p&l spectrum.

208

00:27:44.370 --> 00:27:55.710

Clara Sousa-Silva: and more complex molecules which usually are much harder to do theoretically are no problem for us cool so here you are looking at the skeleton spectrum for the thing daya mean molecule.

209

00:27:56.130 --> 00:28:06.090

Clara Sousa-Silva: And rascal identifies the five functional groups, you see, on the stable and predicts one strong double feature here with a set of meeting features here and a very, very weak feature here.

210

00:28:06.690 --> 00:28:16.920

Clara Sousa-Silva: And it does so correctly is, you see, with a comparison with this measurements, and these are just two examples rascal correctly predicts a comparable skeleton spectra for any molecule is thrown at it.

211

00:28:17.790 --> 00:28:21.690

Clara Sousa-Silva: here's one final example of rascal spectrum, this is glycerine all the height.

212

00:28:22.080 --> 00:28:30.690

Clara Sousa-Silva: it's a molecule present and protoplanetary disks but it's also the simplest sugar crucial for the energy metabolism of all life on Earth so really interesting molecule.

213

00:28:31.350 --> 00:28:43.500

Clara Sousa-Silva: And I would love to show you how well rascal predicts this complex molecule all these functional groups, but I can't because there is no infrared spectrum to compare it to despite this being an incredibly important molecule.

214

00:28:44.580 --> 00:28:53.190

Clara Sousa-Silva: But I can, in the meantime, at least provide some approximate spectral data for glasser are behind and, by extension, for thousands of other molecules and it only takes me a few seconds.

215

00:28:53.640 --> 00:29:03.210

Clara Sousa-Silva: So may not be the most accurate spectrum yet, but it is very quick if you compare it to my fostering spectrum, which took four years you're looking at processes 63 million times faster.

216

00:29:04.620 --> 00:29:17.970

Clara Sousa-Silva: So rascal does all this by predicting the main spectral features over 16,000 molecules which is more molecules in any public database and existence so it's worse data and it's less data, but it is more molecules quantity versus quality.

217

00:29:18.840 --> 00:29:30.180

Clara Sousa-Silva: So for hundreds of molecules for series experimental data for comparison and, by extension, for thousands of molecules for which there is no other data source rascal can correctly approximate infrared spectrum.

218

00:29:30.900 --> 00:29:39.000

Clara Sousa-Silva: And this is the preliminary version of rascal even at this early stage, it can still be very useful and I was going to go through some of the.

219

00:29:40.170 --> 00:29:45.090

Clara Sousa-Silva: applications and future work, but perhaps we don't have time I don't want to go over what you could do, let me know.

220

00:29:45.360 --> 00:29:46.200

Clara Sousa-Silva: All the interruptions.

221

00:29:46.440 --> 00:29:48.000

Clara Sousa-Silva: You sure okay.

222

00:29:49.470 --> 00:29:58.380

Clara Sousa-Silva: I don't like going over Okay, so I won't go through the applications of rascal also there are many, but i'll highlight kind of my favorites that may be useful for people who are here.

223

00:29:58.980 --> 00:30:04.380

Clara Sousa-Silva: So you can look for lots of patterns, by looking may filtering by functional group and molecule type.

224

00:30:05.280 --> 00:30:17.430

Clara Sousa-Silva: But one of the cool things you can do is ask rascal where are good molecular candidates for explaining particular atmospheric features in your data if you have a mystery bump, I can tell you what molecules could cause it.

225

00:30:18.150 --> 00:30:28.290

Clara Sousa-Silva: But what I want to focus on is the rascal can tell you which molecular detections that you would like to make are vulnerable to miss assignments and degeneracy i'll give you one example.

226

00:30:28.800 --> 00:30:32.550

Clara Sousa-Silva: So take a hydrogen cyanide, one of the previous signatures I mentioned earlier.

227

00:30:33.180 --> 00:30:44.370

Clara Sousa-Silva: it's infrared spectrum can be completely explained by this one functional group alone through it's bending motions and stretching motion it forms the three main features of the hydrogen cyanide infrared spectrum.

228

00:30:44.880 --> 00:30:52.050

Clara Sousa-Silva: Which means by seeing these features, maybe you detect hydrogen cyanide, but every other molecule this functional group will have similar features.

229

00:30:52.620 --> 00:30:58.680

Clara Sousa-Silva: For example, acetylene has the same functional within it, and as such they have similar spectrum they're hard to tell apart.

230

00:30:59.190 --> 00:31:09.120

Clara Sousa-Silva: And this isn't just an issue of distinguishing between the two rascal can tell us, but no less than 819 molecules have the same functional group and so will be really hard to tell apart.

231

00:31:10.920 --> 00:31:23.250

Clara Sousa-Silva: The trick that rascal can help you with is by considering other functional groups within the molecules, for example, the most especially active functional group for propane and one beauty is the same as acetylene a hydrogen cyanide.

232

00:31:23.700 --> 00:31:30.720

Clara Sousa-Silva: The rascal can tell you that they have other features that can help you distinguish them from molecules with the same functional group.

233

00:31:31.680 --> 00:31:41.700

Clara Sousa-Silva: So it's really important to note that sometimes the molecule strongest feature is not a molecules most distinguishing feature and any detection that doesn't take that into consideration will be vulnerable to mistakes.

234

00:31:42.750 --> 00:31:52.650

Clara Sousa-Silva: So rascal is great, because it produces approximate spectra for any arbitrary molecule, but it has all sorts of other useful applications are only possible with a large database.

235

00:31:53.430 --> 00:32:05.190

Clara Sousa-Silva: And that's rascal one for us go to which i'm working on here at the CFA I am making many improvements first expanding from the infrared into the optical UV and sub millimeters where possible.

236

00:32:05.820 --> 00:32:15.720

Clara Sousa-Silva: But i'm also estimating band shapes by using quantum chemistry approximations to add flesh to the rascal skeleton spectra so it can be used as cross sections for input into atmospheric models.

237

00:32:16.500 --> 00:32:28.500

Clara Sousa-Silva: And also expanding rascal from the gas phase into liquid and solid spectra so that, for example, we can characterize ISIS on Pluto an icy moves, this is actually work, I became I began, many years ago, when I was a master student.

238

00:32:30.030 --> 00:32:39.240

Clara Sousa-Silva: And finally i'm harvesting absolute intensities from lab data, where it exists and from standard machine and learn machine learning quantum simulations.

239

00:32:39.750 --> 00:32:47.790

Clara Sousa-Silva: such as these that you see on the screen, where I can do them quickly i've already done some of this work with a student collaboration, the University of new South Wales.

240

00:32:49.320 --> 00:32:54.060

Clara Sousa-Silva: And for the molecules we care about the most we can do it the hard way like I did it for fostering.

241

00:32:54.420 --> 00:33:00.840

Clara Sousa-Silva: I just won't be able to do this for all the molecules nowhere anywhere near all the molecules, which is why rascal so important.

242

00:33:01.290 --> 00:33:07.650

Clara Sousa-Silva: Given how difficult it is to obtain high quality data for those thousands of molecules thousands of potential atmospheric gases.

243

00:33:08.040 --> 00:33:19.680

Clara Sousa-Silva: is crucial that we invest in intermediate approximate steps to obtaining spectra that can be gradually improved upon, so that one day we can do more than just tentatively detect a promising bio signature like philosophy.

244

00:33:20.820 --> 00:33:31.290

Clara Sousa-Silva: Because, as much as I like phosphenes which I do, and I also like the more traditional bio signature, such as a methane I don't think the detection of life will come from a single molecule.

245

00:33:31.830 --> 00:33:35.760

Clara Sousa-Silva: As the Venus story shows the detection of life will likely be uncertain.

246

00:33:36.240 --> 00:33:44.130

Clara Sousa-Silva: And that uncertainty will only be reduced, with we are willing to both detect and understand more molecules even if they're not popular abundant.

247

00:33:44.640 --> 00:33:49.410

Clara Sousa-Silva: Because it may be harder to detect to trace gas that has small impact on atmosphere spectrum.

248

00:33:49.710 --> 00:33:55.920

Clara Sousa-Silva: But we want to reduce our chances of false positives and consequently increase our chances of actually confirming life.

249

00:33:56.250 --> 00:34:05.550

Clara Sousa-Silva: We have to be willing to consider the big picture, not just a few promising molecules but all possible molecules that can together help us reduce the ambiguity in the direction of life.

250

00:34:06.540 --> 00:34:13.170

Clara Sousa-Silva: But today we are not prepared to both detect and confirm the presence of most molecules are an exoplanet.

251

00:34:13.650 --> 00:34:21.360

Clara Sousa-Silva: So my biggest professional concern is not that will fail to detect a habitable planet in our lifetime and even an inhabited planet in our lifetime.

252

00:34:21.900 --> 00:34:28.770

Clara Sousa-Silva: My biggest professional concerns that will point our telescopes directly at an inhabited planet and not have the tools to know it.

253

00:34:29.550 --> 00:34:40.260

Clara Sousa-Silva: So with computational chemistry and collaborations with scientists of all ages, I aim to provide the spectroscopic toolkit that will allow us to one day, no life when we see it, thank you.

254

00:34:48.180 --> 00:34:49.170

Morgan Elowe MacLeod: Thank you so much.

255

00:34:51.570 --> 00:35:01.440

Morgan Elowe MacLeod: So I want to start a conversation by just reminding everyone that they can private message me and I will call on you to speak up.

256

00:35:02.880 --> 00:35:09.300

Morgan Elowe MacLeod: But I wondered if we could talk a little bit for someone who's not a spectroscopy just.

257

00:35:10.530 --> 00:35:18.360

Morgan Elowe MacLeod: Something that you touched on in a couple places is kind of the distinction between features.

258

00:35:19.500 --> 00:35:31.470

Morgan Elowe MacLeod: And the incredible number of features that can populate a molecular spectrum, even if we're talking about like a pure molecular spectrum of just one gas.

259

00:35:32.910 --> 00:35:46.050

Morgan Elowe MacLeod: And then I imagine that you know if we think about like earth's biosphere there's even more than one like biomarker presence so like it must be even more messy so.

260

00:35:47.280 --> 00:35:58.140

Morgan Elowe MacLeod: Can you talk a little bit about how you know low resolution spectrum like we would be able or a comparatively low resolution spectrum like we would be able to take.

261

00:35:59.250 --> 00:36:13.770

Morgan Elowe MacLeod: an astronomical source do those lines add together in a way that it's sort of their like cumulative equivalent with within some wavelength range versus like having single features so.

262

00:36:16.380 --> 00:36:28.830

Morgan Elowe MacLeod: i'm coming at this a little bit from you know in supernovae people talk a lot about iron line blanketing so that's a context that i'm personally a little bit more familiar with, but I wondered if we could kind of start there with.

263

00:36:29.250 --> 00:36:42.090

Morgan Elowe MacLeod: What is it that we're really observing and we observing individual features, if we were to observe this in two decades with an exoplanet or which aw's or are we observing their like cumulative effect.

264

00:36:43.380 --> 00:36:44.040

Clara Sousa-Silva: So.

265

00:36:45.150 --> 00:36:57.120

Clara Sousa-Silva: Yes, atomic spectra is a little hard it's very hard in many ways, but it's a little easier in many ways, because you're looking at single lines with molecular spectra, as you can imagine there's more complexity and would that come more lines.

266

00:36:57.510 --> 00:37:06.000

Clara Sousa-Silva: In the microwave we're still able to sometimes be able to isolate individual lines, and that was that was what we were trying to do on Venus with phosphenes a single transition.

267

00:37:06.300 --> 00:37:13.890

Clara Sousa-Silva: I point out out of those 16.8 billion transitions that I worked on so just the one that we are trying to find on Venus.

268

00:37:14.370 --> 00:37:27.030

Clara Sousa-Silva: So there are times we can try to identify single transitions but yes, most of the time you're looking at bands, so a combined opacity from often millions and millions of features.

269

00:37:27.630 --> 00:37:32.730

Clara Sousa-Silva: Still varies a lot between wavelength so say in the infrared it's very common for.

270

00:37:33.510 --> 00:37:46.170

Clara Sousa-Silva: Many atoms molecules to have features are quite distinctive and then, as you move towards the optical movie where there are many, many energy levels that can be occupied, but each are not very likely to be occupied.

271

00:37:46.500 --> 00:37:56.340

Clara Sousa-Silva: The result is we call them weeds because, instead of getting flat baselines which sharp features you just get these on July eating rolling hills of spectra.

272

00:37:56.400 --> 00:38:00.030

Clara Sousa-Silva: Where it's so hard to distinguish one molecule from another.

273

00:38:00.870 --> 00:38:03.780

Clara Sousa-Silva: And this is just talking about individual molecules.

274

00:38:04.110 --> 00:38:11.880

Clara Sousa-Silva: If we're looking at atmosphere it's not a bunch of molecules going about their business and aware of their neighbors they're colliding with one another, exchanging energy with one another.

275

00:38:12.090 --> 00:38:21.570

Clara Sousa-Silva: Which not just broadens the features it shifts the features that it's chaos and when I say we're missing spectra for most molecules that's just the pure spectrum.

276

00:38:21.780 --> 00:38:30.450

Clara Sousa-Silva: Right, we are worse at figuring out what that spectral look like when the molecules are colliding with one another, which, sadly, is literally every time we found them.

277

00:38:30.870 --> 00:38:36.240

Clara Sousa-Silva: On on atmospheres you never just get you know isolated philosophy and atoms and molecules.

278

00:38:36.600 --> 00:38:43.860

Clara Sousa-Silva: So, in answer to your question it varies, and it depends not just on resolution but kind of localized context of what's happening to those.

279

00:38:44.220 --> 00:38:56.580

Clara Sousa-Silva: molecules what temperature, what pressure is the pressure caused by things like CO2 a very successful collision of molecule that just exchanges, energy and ruins all the molecule spectrum.

280

00:38:57.090 --> 00:39:07.710

Clara Sousa-Silva: which by the way, is a problem on Venus which is basically all carbon dioxide So yes, it is much more complicated than bad enough, and you cannot go for single features, but.

281

00:39:08.520 --> 00:39:15.990

Clara Sousa-Silva: that's a problem on top of my current problems which, as you can tell are many and would last me lifetimes to resolve on their own.

282

00:39:16.230 --> 00:39:21.780

Morgan Elowe MacLeod: yeah and I didn't ask from a point of like pessimism or pure pessimism.

283

00:39:24.060 --> 00:39:27.150

Morgan Elowe MacLeod: It seems like some of the work that you're doing to like add.

284

00:39:28.320 --> 00:39:39.240

Morgan Elowe MacLeod: sort of like line width or like cumulative line with to the groups in rascal two tix is like addressing some of what I was asking about.

285

00:39:39.720 --> 00:39:58.500

Clara Sousa-Silva: Yes, yeah so rascal be less crap very soon, but it will still be very much you know in capable of doing a lot of the very complicated modeling that will need to really understand you know, a biosphere holistically for lack of better words, yes I make sense.

286

00:39:59.580 --> 00:40:04.920

Morgan Elowe MacLeod: Towards a holistic atmosphere, have you had a question about Venus would you like to go ahead.

287

00:40:06.240 --> 00:40:13.890

Abraham Loeb: Oh sure, so I mean there was the report in the New York Times, but, but if we look at the archive that there was.

288

00:40:14.370 --> 00:40:25.560

Abraham Loeb: Some criticism world first about the statistical significance of the detection of those fines and then some other people suggest maybe so to is confused with the line and perhaps.

289

00:40:27.420 --> 00:40:37.620

Abraham Loeb: There is, for chronic activity that can produce it, can you comment about these various criticisms and just explain why you believe that it's a real detection.

290

00:40:39.240 --> 00:40:48.810

Clara Sousa-Silva: Oh, I don't I don't believe it any more than I think any responsible scientists does that team that i'm part of and i'm not involved in the data reduction so i'm kind of just trusting the experts.

291

00:40:49.380 --> 00:40:59.580

Clara Sousa-Silva: And they still think the signal is real and other teams think so, too, but not all, so there are ways of reducing the data, where the signal disappear so maybe the signal is not real.

292

00:41:00.090 --> 00:41:08.550

Clara Sousa-Silva: But even if the signal is real, indeed, when we were looking for candidates to explain the signal faustino is our favorite for our second favorite was so to.

293

00:41:09.150 --> 00:41:13.830

Clara Sousa-Silva: Now, so to was dismissed for variety of reasons, the kind of the easiest one to explain is that.

294

00:41:14.280 --> 00:41:20.820

Clara Sousa-Silva: In the band past, there are other locations where so to should be absorbing, and so we looked there, and there was no so too.

295

00:41:21.300 --> 00:41:31.860

Clara Sousa-Silva: So it can just disappear easily, though there are ways of having enormous variability, and so we ended up does missing, so too, for various reasons, including this one.

296

00:41:32.520 --> 00:41:40.020

Clara Sousa-Silva: And, but so to would also be a strange thing to find where we found it the distribution vessel to between kind of.

297

00:41:40.350 --> 00:41:47.130

Clara Sousa-Silva: Above the clouds within the clouds and beneath the clouds are things we still don't understand now when I say it would be weird to find it.

298

00:41:47.460 --> 00:41:55.200

Clara Sousa-Silva: it's not as weird as finding phosphenes so obviously something worth exploring, but these are all things we considered I should point out that.

299

00:41:55.590 --> 00:42:04.260

Clara Sousa-Silva: there's a lot of kind of criticism of lots of work and infighting and things like this, but this is just a bunch of very good.

300

00:42:04.830 --> 00:42:17.490

Clara Sousa-Silva: Very well meaning people trying to interpret very difficult very noisy very delicate data and discoveries made at the edge of instrument capabilities will always lead to discussion as they should.

301

00:42:17.910 --> 00:42:24.930

Clara Sousa-Silva: Because if we could just look at Venus go yay phosgene aliens we would have done it and it's really hard so.

302

00:42:26.580 --> 00:42:38.190

Clara Sousa-Silva: i'm not involved in the data reduction I don't really want to be defending something I don't understand completely but that's kind of the general summary, it seems like these are huge disagreements, but they're not it's things like.

303

00:42:38.490 --> 00:42:40.620

Clara Sousa-Silva: Oh, the upper limit of fostering has to be.

304

00:42:40.980 --> 00:42:53.250

Clara Sousa-Silva: five parts per billion and we go, I think there are seven and this seems like a huge disagreement because it's basically someone saying we found fasting and someone saying we didn't win actually it's a two part per billion difference potentially so.

305

00:42:53.940 --> 00:43:00.000

Abraham Loeb: Did you feel that some of the criticism wasn't fair and then mean spirited or did you feel that his.

306

00:43:02.400 --> 00:43:09.120

Clara Sousa-Silva: son was perhaps a little clumsy I would save, but I think it's mostly collegiate and while meaning and I don't I.

307

00:43:09.690 --> 00:43:15.540

Clara Sousa-Silva: This is exactly the sort of discussion that I would have been disappointed if it was absent, if we had.

308

00:43:15.990 --> 00:43:27.330

Clara Sousa-Silva: claimed a detection of a potential bio signature next door and everyone went great work let's move on, that would have been a horrific disappointment and so i'm really pleased that.

309

00:43:27.780 --> 00:43:35.700

Clara Sousa-Silva: It has led to this debate, because this isn't our last time I feel like this is our rehearsal for next time we find a bio signature and.

310

00:43:36.210 --> 00:43:45.000

Clara Sousa-Silva: I want to do better next time, by which I mean be better prepared with a better toolkit with more transitions and i've always been against.

311

00:43:45.720 --> 00:43:53.100

Clara Sousa-Silva: As you've seen from my talk detecting a molecule with a single feature, because obviously it's very easy to make mistakes and with.

312

00:43:53.340 --> 00:44:02.970

Clara Sousa-Silva: Venus we would have loved to have additional features, so we could confirm its philosophy and that's very much where my efforts are at following up with Venus to try and get more features.

313

00:44:03.540 --> 00:44:11.100

Clara Sousa-Silva: But no, I don't I definitely don't think people are mean spirited everyone's just trying their best and also it's a pandemic, we can all go easy on each other.

314

00:44:13.950 --> 00:44:18.060

Morgan Elowe MacLeod: that's a good yeah lesson for life right now.

315

00:44:20.700 --> 00:44:28.380

Morgan Elowe MacLeod: Would you like to go ahead with some discussion about like the stellar type and how that relates to detecting.

316

00:44:29.130 --> 00:44:35.490

Ana Bonaca: Yes, I remember, I have a special you mentioned for fasting, by the way, really nice Thank you.

317

00:44:36.900 --> 00:44:46.470

Ana Bonaca: yeah and yeah So the question is, you mentioned that philosophy is more difficult to detect and solar type and type stars and now you're sort of talking about different.

318

00:44:46.740 --> 00:44:55.110

Ana Bonaca: molecules I was wondering if well first like why that is, for, in case of pain and then second like does this apply to otter by signatures as well and.

319

00:44:55.410 --> 00:45:02.430

Ana Bonaca: Could this kind of potentially lead to kind of a bias of what kind of life, we can detect because you're saying that to.

320

00:45:02.820 --> 00:45:12.540

Ana Bonaca: Like those by our by signatures are not unique So if you need like a combination of those, but you can only text or grammatical since that was star six and then that's what I was wondering.

321

00:45:13.350 --> 00:45:23.010

Clara Sousa-Silva: No totally for a question, so this is a complicated game with many parameters in the case of the stellar type it kind of does affect almost all bio signatures because.

322

00:45:23.190 --> 00:45:27.810

Clara Sousa-Silva: You can consider so i'll be really simplistic if there are any stellar astronomers here, please forgive me.

323

00:45:28.470 --> 00:45:40.200

Clara Sousa-Silva: But you can kind of think of you know quiet em dwarfs and then active em dwarfs and some like stars and kind of growing degrees of radiation levels and what they do is cause photo.

324

00:45:40.680 --> 00:45:50.610

Clara Sousa-Silva: association of the molecule so this fatalities that can destroy molecules, namely bio signatures gets worse as you move down these stereotypes.

325

00:45:51.120 --> 00:45:54.060

Clara Sousa-Silva: So when I first did my models actually did quite em dwarfs and.

326

00:45:54.330 --> 00:46:02.670

Clara Sousa-Silva: flossing could totally survive and all these other buyers signatures and then someone said, you know there's no quiet i'm door so that seems a little disingenuous and I was like you're right.

327

00:46:02.970 --> 00:46:12.300

Clara Sousa-Silva: Maybe we haven't found them, but I just took that out because, yes, you could be attacked by a signature, but probably those stars exist so maybe not a good.

328

00:46:12.960 --> 00:46:19.170

Clara Sousa-Silva: target but indeed with active indoors fusing struggle much more survive and many other molecules biosensors did.

329

00:46:19.830 --> 00:46:26.910

Clara Sousa-Silva: Because, by the time they get to observe the layers of the atmosphere, to get destroyed now there are ways of avoiding this and.

330

00:46:27.420 --> 00:46:33.870

Clara Sousa-Silva: With protection so some molecules can work as scavengers as protectors of the other bio signatures.

331

00:46:34.320 --> 00:46:43.230

Clara Sousa-Silva: And these vary depending on stellar type planetary type and atmospheric composition, you can also get hayes's they're very good at protecting by a signature.

332

00:46:43.590 --> 00:46:56.430

Clara Sousa-Silva: But then we can see through them like with Venus so the sort of environments that may be, create a protective layer and allow for biosensors to occur, often also shield them from being visible to us.

333

00:46:57.030 --> 00:47:10.140

Clara Sousa-Silva: If we can see it, maybe radiation can also get through and destroy them, so this becomes a delicate game with small windows of opportunity as factually speaking, where we can see these bio signatures and it varies enormously on.

334

00:47:11.250 --> 00:47:22.110

Clara Sousa-Silva: super versus a smaller planets planets that have hydrogen rich atmospheres versus nitrogen rich atmospheres, and so this combination this complicated game.

335

00:47:22.500 --> 00:47:30.840

Clara Sousa-Silva: has many a very large parameter space and playing around and those and figuring out what are our windows of observation and that's kind of what i'm trying to do.

336

00:47:32.490 --> 00:47:46.170

Ana Bonaca: that's super interesting and, like the word with rascal that when you're mapping all those kind of spec trend it visually like do they add up in this game of like scavenger molecules like so so.

337

00:47:47.340 --> 00:47:52.290

Ana Bonaca: Does this provide you the tools to kind of simulate such environment as well.

338

00:47:53.610 --> 00:47:55.950

Clara Sousa-Silva: Very roughly so they just if you.

339

00:47:56.160 --> 00:48:00.270

Clara Sousa-Silva: If I know it's a method rich atmosphere and that's one of the things rascal can do.

340

00:48:00.330 --> 00:48:10.890

Clara Sousa-Silva: It can tell you what are the windows already because I already know that and tell you which molecules are good for being detected in those windows, they can also tell you which molecules only have one feature and those windows meaning.

341

00:48:11.460 --> 00:48:18.480

Clara Sousa-Silva: detecting it and ambiguously will be very difficult, as we just saw with Venus and which have two or more meaning, you could do play a game of.

342

00:48:19.080 --> 00:48:28.860

Clara Sousa-Silva: unambiguously assigning in so very difficult the possible and i'm i'm kind of just trying to do the first very clumsy step into exactly that toolkit.

343

00:48:30.000 --> 00:48:31.170

Ana Bonaca: that's pretty cool things.

344

00:48:32.520 --> 00:48:33.630

Morgan Elowe MacLeod: is really interesting.

345

00:48:34.860 --> 00:48:41.850

Morgan Elowe MacLeod: So Oh, we just have another question Martin, would you like to speak up about i'm dwarfs.

346

00:48:42.330 --> 00:48:54.780

Clara Sousa-Silva: Oh yeah I just saw that I can read the letter, so the question is, if it does struggle on active endorse it is a good biomarker

because it must be produced continuously to be detectable if you know the
halftime you can use it sorry no microphone here.

347

00:48:55.020 --> 00:48:56.430

Morgan Elowe MacLeod: Oh, I didn't see that but yeah.

348

00:48:57.720 --> 00:49:02.100

Clara Sousa-Silva: And yeah so absolutely and, but it is a bit of a game
right you wanted to be.

349

00:49:02.700 --> 00:49:12.150

Clara Sousa-Silva: To have a short enough half live and lifetime, that if
you see it, you know it's a good bio signature, at least to some extent,
because it has to be continuously produced.

350

00:49:12.540 --> 00:49:19.830

Clara Sousa-Silva: But if it's being destroyed too quickly to accumulate
to detectable levels, then you just won't see it at all, so you also have
a very small window where.

351

00:49:20.370 --> 00:49:31.410

Clara Sousa-Silva: it's a good buy a second Sherwood low false positives,
but you can see it and and this dance is not straightforward So yes, but
that comes with downsides.

352

00:49:32.700 --> 00:49:34.080

Morgan Elowe MacLeod: Interesting character.

353

00:49:36.210 --> 00:49:51.900

Gary Melnick: I have a quick question about aws T, do you know whether
aws it will have the ability to detect some of these biomarkers and, in
particular it's my understanding that.

354

00:49:53.430 --> 00:50:08.100

Gary Melnick: You need to integrate for a long time to detect some of
these spectral features and J w s T was not built to integrate down the
noise for the length of time needed to detect the species.

355

00:50:08.640 --> 00:50:21.030

Gary Melnick: So i'm wondering if you've looked at these issues and
you've isolated a set of potential targets that are suitable for aws Ts
capabilities.

356

00:50:22.500 --> 00:50:32.880

Clara Sousa-Silva: And so excellent question, and this is something we looked into a lot, so one of the planets scenarios I didn't mention was CO2 rich atmospheres around sun like stars.

357

00:50:33.240 --> 00:50:48.300

Clara Sousa-Silva: were technically I found that Jacob St could detect them, but it would have to use its entire cryogenic lifetime to get a good enough signal to noise ratio, so I didn't mention this and didn't add it to the paper, because that would be really disingenuous.

358

00:50:48.720 --> 00:50:50.880

Morgan Elowe MacLeod: And that should be no problem for all of you.

359

00:50:53.040 --> 00:51:05.430

Clara Sousa-Silva: But, but that was exactly simply we took into consideration kind of how many observation hours would it take and our most favorable scenarios We only need a few 10s of observation hours to be able to get a really robust signal to noise ratio.

360

00:51:05.700 --> 00:51:10.050

Clara Sousa-Silva: But in others will take hundreds and i've kind of mentioned this in the paper but.

361

00:51:10.740 --> 00:51:18.960

Clara Sousa-Silva: i'm not really an observer, are only proposed for like to observe alterations my whole life and they were both of Venus and both in the last year, so i'm very new to that field but.

362

00:51:19.200 --> 00:51:24.480

Clara Sousa-Silva: We definitely took that into account, and it was for someone who's coming from a different field.

363

00:51:25.140 --> 00:51:37.020

Clara Sousa-Silva: Really heartbreaking because we were running these simulation were like Oh, we could totally look at that spectrum could totally see fall scene and then I figure out how many hours of jaded St observation, we will need and it's just you know 208.

364

00:51:37.470 --> 00:51:44.190

Clara Sousa-Silva: And, and I just gave up on that So yes, definitely consideration I haven't got to the point where I.

365

00:51:44.910 --> 00:51:52.380

Clara Sousa-Silva: Have simulated all the possible scenarios, with all the possible molecules to try and figure out what Judo St can and cannot do and where the best targets.

366

00:51:52.860 --> 00:52:03.900

Clara Sousa-Silva: But if anyone here has kind of the chops to do that, I would love to collaborate because observing is very much new to me i'm a theoretician and not even a theoretician in astronomy so.

367

00:52:04.470 --> 00:52:06.420

Clara Sousa-Silva: This is what, let me just mention as.

368

00:52:06.600 --> 00:52:07.980

Gary Melnick: A cautionary note.

369

00:52:11.040 --> 00:52:11.430

Gary Melnick: For.

370

00:52:12.480 --> 00:52:28.260

Gary Melnick: An instrument like of those on aws T they're built to attain a certain stability and what that means is that, even at their listed sensitivity you could integrate for.

371

00:52:28.800 --> 00:52:44.340

Gary Melnick: 10,000 hours and your signal to noise will plateau it will not continue to go down as the square root of time because there's an inherent instability in inherent noise in the instrument so.

372

00:52:44.700 --> 00:53:01.380

Gary Melnick: As you look at this with che wc I would just caution you that it's more than just looking at sensitivity and assuming radio metric performance of the instrument, there will be a noise floor you can't go below so just.

373

00:53:02.370 --> 00:53:11.940

Gary Melnick: Just a note that even a 200 hours are 100 hours of integration Jay who may not be able to do what you want.

374

00:53:13.170 --> 00:53:24.030

Clara Sousa-Silva: Yes, quite possibly I i'm very willing to believe that I have to chop everything in half or double all the outpatient time zone or an plateaus are hit.

375

00:53:24.540 --> 00:53:28.170

Clara Sousa-Silva: These were the codes, we use that include noise floor but.

376

00:53:28.590 --> 00:53:39.570

Clara Sousa-Silva: And so i'm thinking, the most favorable scenarios may be possible, but that's really as far as i'm willing to promise and we only use \$1 Steve because that's kind of new future and we have access to some.

377

00:53:40.470 --> 00:53:49.110

Clara Sousa-Silva: simulations that allow us to do, but this sort of work has likely only going to be truly useful for the of the next generation of telescopes.

378

00:53:50.520 --> 00:53:51.990

Morgan Elowe MacLeod: Oh let's go back to the lab.

379

00:53:53.430 --> 00:53:57.810

Clara Sousa-Silva: yeah in the meantime, we have, we need more spectra anyway, because we can see, most of the molecules.

380

00:54:01.830 --> 00:54:04.170

Clara Sousa-Silva: let's so someone has a question yeah.

381

00:54:04.500 --> 00:54:15.780

Phillip Cargile: yeah sorry um so fantastic talk, thank you very much so, coming from a stellar spectroscopy this point of view, one of the main hurdles there is reconciling difference between.

382

00:54:16.200 --> 00:54:25.200

Phillip Cargile: The laboratory measurements of oscillators strings of iron, for instance, and the predictions quantum mechanical predictions how well are we doing with these molecules or.

383

00:54:25.740 --> 00:54:35.040

Phillip Cargile: Are they are the quantum quantum mechanics in agreement with the labs or like the wavelengths are way offer the oscillator strings way off or anything like that.

384

00:54:36.360 --> 00:54:51.360

Clara Sousa-Silva: So kind of the short answer is, if you can have experimental measurements in that region, you should use those would be kind of my shorter answer so if it's in high trend in that region take it and but.

385

00:54:52.080 --> 00:55:00.150

Clara Sousa-Silva: The problem is, they may be other regions where it's active and there's just no data, so you need to make some choices and the other.

386

00:55:00.630 --> 00:55:11.190

Clara Sousa-Silva: The easiest explanation I can give is, you should always trust the positions and measurements and you could probably do well with trusting the intensity of the simulations.

387

00:55:11.700 --> 00:55:20.970

Clara Sousa-Silva: Because when you measuring it's often very difficult to get the baseline clean enough to know the true intensity and it's very hard to know how much that varies with temperature.

388

00:55:21.360 --> 00:55:29.940

Clara Sousa-Silva: From one measurement at a single temperature and so intensities tend to be a little better with theory and positions tend to be better with measurements.

389

00:55:30.510 --> 00:55:42.120

Clara Sousa-Silva: Now, with big molecules simulations high performance computing simulations they tend to get really bad really quickly as soon as you get to like five atoms and that's where rascal is trying to step in.

390

00:55:42.660 --> 00:55:52.110

Clara Sousa-Silva: And because rascal doesn't care how big a molecule is and but the matrices just get completely undiagnosed sizable was once you get to.

391

00:55:53.250 --> 00:55:57.810

Clara Sousa-Silva: high expectations and with big molecules you need there's lots of things to do.

392

00:55:58.530 --> 00:56:12.210

Clara Sousa-Silva: So it varies but yes measurement central be better at frequencies theory tend to have better intensities but both benefit from one another and so often people imagine that we're competing with one another and i'm not going to lie sometimes there's some you know.

393

00:56:12.570 --> 00:56:31.680

Clara Sousa-Silva: rough word spoken and conferences, but mostly we need each other very much all of my work would have been impossible to refine the theory without reliable experiments that I could trust and benchmark

against mine, so we kind of need them both but yes, they have their strengths and downsides.

394

00:56:32.970 --> 00:56:33.240

Phillip Cargile: Thank you.

395

00:56:34.230 --> 00:56:35.280

Morgan Elowe MacLeod: So can I.

396

00:56:36.390 --> 00:56:45.150

Morgan Elowe MacLeod: Can I I guess pose a little bit of a question but also just give you this last minute or two to sort of have the last word I something sort of.

397

00:56:46.650 --> 00:57:01.650

Morgan Elowe MacLeod: That came up up to me again and again through what you showed is that if we have approximate identifiers of molecules we can kind of take a learning approach of like maybe we see certain lines in a spectrum.

398

00:57:03.210 --> 00:57:05.580

Morgan Elowe MacLeod: Maybe it's a solar system spectrum, maybe it's.

399

00:57:07.620 --> 00:57:09.930

Morgan Elowe MacLeod: Extra solar and then.

400

00:57:11.490 --> 00:57:22.980

Morgan Elowe MacLeod: You with your line identifications of from sort of an approximate code like rascal can tell us what like candidate molecules are and then you could follow those up with more in depth.

401

00:57:24.450 --> 00:57:37.710

Morgan Elowe MacLeod: sort of study, do you think there's a prospect for essentially empirically using the astronomical spectra to learn more about the spec like full spectrum of a molecule like.

402

00:57:38.730 --> 00:57:41.970

Morgan Elowe MacLeod: One of these complex molecules that's hard to compute.

403

00:57:43.410 --> 00:57:46.650

Morgan Elowe MacLeod: Or is the lab is going to be our point of reference.

404

00:57:48.120 --> 00:57:54.630

Clara Sousa-Silva: Know we've used we've used astronomical spectra to calibrate things, yes, particularly at high temperatures, you need spectra from.

405

00:57:55.080 --> 00:58:04.140

Clara Sousa-Silva: cool stars which aren't that cool but cool enough to have quite a lot of molecules and and we can identify the molecules by you know famous bands and things like that, and then.

406

00:58:04.140 --> 00:58:05.430

Clara Sousa-Silva: See how they vary with.

407

00:58:05.460 --> 00:58:09.840

Clara Sousa-Silva: The very high temperatures we wouldn't be able to simulate in a you know, in the lab and all.

408

00:58:10.290 --> 00:58:21.240

Clara Sousa-Silva: those sorts of temperatures easily and safely for all the molecules we care about So yes, we have in the past used an astronomical spectra to calibrate pure spectra that we have from the lab and from theory.

409

00:58:21.810 --> 00:58:32.280

Clara Sousa-Silva: And so yeah maybe it's a tripod you know astronomical spectra lab spectra theoretical spectra ideally working together and intuitively I mean not the solar specter they don't care what we do, but.

410

00:58:32.880 --> 00:58:38.700

Clara Sousa-Silva: You know, but in using all of this data interpretively to improve on another definitely something that is done.

411

00:58:39.030 --> 00:58:47.790

Clara Sousa-Silva: I should point out in the less positive note that these fields don't necessarily communicate with each other, particularly well, so there is a lot of information lost along the way.

412

00:58:50.250 --> 00:58:51.420

Clara Sousa-Silva: Oh, and I get the last word.

413

00:58:51.630 --> 00:58:57.120

Clara Sousa-Silva: yeah and you have you are interested in being mentors for my average program and you don't completely hate children.

414

00:58:57.480 --> 00:59:06.060

Clara Sousa-Silva: And you should join, we always need more mentors and we also need funding, because we can pay the mentors, but we do pay the kids I get money to pay the kids the kids get paid.

415

00:59:07.110 --> 00:59:07.950

Morgan Elowe MacLeod: it's really wonderful.

416

00:59:09.240 --> 00:59:21.300

Morgan Elowe MacLeod: Well Thank you everyone Thank you Clara we're delighted to have you at the CFA to the maximum extent that's possible and thanks for sharing this hour together.

417

00:59:22.170 --> 00:59:23.280

Clara Sousa-Silva: Thank you for having me.