
AB
GRAD
CON23

1
00:00:13,490 --> 00:00:10,870
[Music]

2
00:00:14,629 --> 00:00:13,500
good morning everyone

3
00:00:17,269 --> 00:00:14,639
um we're at the awesome my name is

4
00:00:19,070 --> 00:00:17,279
Andrea Brian I'm a PhD student at

5
00:00:21,109 --> 00:00:19,080
University Chicago and today I will talk

6
00:00:22,970 --> 00:00:21,119
about investigating the use of long

7
00:00:25,550 --> 00:00:22,980
period seismology to explore Titan's

8
00:00:26,990 --> 00:00:25,560
interior I'm aware that

9
00:00:28,670 --> 00:00:27,000
um I'm actually quite new to seismology

10
00:00:31,550 --> 00:00:28,680
myself when we began a couple years ago

11
00:00:33,470 --> 00:00:31,560
so I will try to do a little bit of

12
00:00:37,190 --> 00:00:33,480
background for everyone all right so

13
00:00:39,170 --> 00:00:37,200

starting with Cassini we learned a lot

14
00:00:41,750 --> 00:00:39,180
about the saturnian system but

15
00:00:44,750 --> 00:00:41,760
especially for this study we learned a

16
00:00:45,950 --> 00:00:44,760
lot about Titan and so

17
00:00:47,090 --> 00:00:45,960
um there was actually a probe the

18
00:00:49,069 --> 00:00:47,100
hoyigan's probe that landed on the

19
00:00:51,950 --> 00:00:49,079
surface of Titan and you can if you go

20
00:00:55,790 --> 00:00:51,960
on YouTube you can Google it and or you

21
00:00:57,529 --> 00:00:55,800
can YouTube it and see the landing um

22
00:00:59,450 --> 00:00:57,539
there it's leaning through the haze and

23
00:01:00,709 --> 00:00:59,460
you see some water ice Pebbles on the

24
00:01:02,990 --> 00:01:00,719
surface

25
00:01:04,549 --> 00:01:03,000
um and there's so much I could say about

26
00:01:06,230 --> 00:01:04,559
Titan but for the sake of time I'll just

27
00:01:08,390 --> 00:01:06,240
say it's an amazing natural astrobiology

28
00:01:10,490 --> 00:01:08,400
Laboratory

29
00:01:13,490 --> 00:01:10,500
um and um

30
00:01:14,510 --> 00:01:13,500
I'm very excited to do some theory about

31
00:01:16,670 --> 00:01:14,520
it

32
00:01:19,910 --> 00:01:16,680
um okay so here is what we currently

33
00:01:22,370 --> 00:01:19,920
know about Titan

34
00:01:24,649 --> 00:01:22,380
um and so we know that there is a liquid

35
00:01:26,390 --> 00:01:24,659
water ocean underneath

36
00:01:29,570 --> 00:01:26,400
um a very thick shell of ice so it's

37
00:01:30,950 --> 00:01:29,580
between 50 and 150 kilometers deep

38
00:01:34,010 --> 00:01:30,960

um we don't know the exact compositions

39
00:01:37,190 --> 00:01:34,020
of this ice shell or the ocean but we do

40
00:01:39,109 --> 00:01:37,200
know that there's water there

41
00:01:41,330 --> 00:01:39,119
um and also there could be some high

42
00:01:42,910 --> 00:01:41,340
pressure ice underneath the ocean and

43
00:01:46,010 --> 00:01:42,920
this actually has very big

44
00:01:47,210 --> 00:01:46,020
astrobiological implications because it

45
00:01:48,789 --> 00:01:47,220
could actually act if there is high

46
00:01:51,469 --> 00:01:48,799
pressurized it could act as a barrier

47
00:01:53,870 --> 00:01:51,479
from there's the enrichment of the ocean

48
00:01:56,389 --> 00:01:53,880
for potential life

49
00:01:58,490 --> 00:01:56,399
um if it's there and so

50
00:01:59,990 --> 00:01:58,500
um yeah so that's something that

51
00:02:01,969 --> 00:02:00,000
seismology can help us to constrain

52
00:02:04,609 --> 00:02:01,979
whether or not that's there

53
00:02:07,670 --> 00:02:04,619
um okay so this brings me to NASA

54
00:02:12,410 --> 00:02:07,680
dragonfly and to dragonfly

55
00:02:13,910 --> 00:02:12,420
um is a rotor craft that will launch in

56
00:02:15,229 --> 00:02:13,920
2027

57
00:02:16,910 --> 00:02:15,239
um and it'll take about six years or so

58
00:02:18,949 --> 00:02:16,920
to get to Titan

59
00:02:20,270 --> 00:02:18,959
um but this instrument will be loaded

60
00:02:23,210 --> 00:02:20,280
with many many different instrument

61
00:02:25,250 --> 00:02:23,220
packages that are really there's a very

62
00:02:27,410 --> 00:02:25,260
large Focus for Astro bio and in

63
00:02:28,670 --> 00:02:27,420

particularly the seismometer

64
00:02:30,470 --> 00:02:28,680
um which is going to be on the other

65
00:02:33,410 --> 00:02:30,480
Underside you can see here it's like

66
00:02:35,089 --> 00:02:33,420
dangling or it's up under the rotocraft

67
00:02:37,190 --> 00:02:35,099
but it's going to be tethered it's

68
00:02:39,110 --> 00:02:37,200
tethered and so it'll be lowered down at

69
00:02:41,990 --> 00:02:39,120
each location on Titan that's going to

70
00:02:44,030 --> 00:02:42,000
visit and then measure the seismic

71
00:02:45,830 --> 00:02:44,040
activity there and there also these

72
00:02:47,630 --> 00:02:45,840
geophones which are essentially less

73
00:02:49,550 --> 00:02:47,640
sensitive seismometers and they're a bit

74
00:02:53,509 --> 00:02:49,560
smaller that are going to be there's two

75
00:02:55,610 --> 00:02:53,519
under the underside of the skids and so

76
00:02:57,530 --> 00:02:55,620
in particular the seismometer the

77
00:03:00,830 --> 00:02:57,540
geophones and other instruments within

78
00:03:04,729 --> 00:03:00,840
the this drag map package are going to

79
00:03:08,270 --> 00:03:04,739
be looking to measure habitability

80
00:03:11,030 --> 00:03:08,280
okay so um dragonfly says melody

81
00:03:12,890 --> 00:03:11,040
seismology in a nutshell will help us to

82
00:03:17,030 --> 00:03:12,900
constrain the interior structure of

83
00:03:18,830 --> 00:03:17,040
Titan more precisely and so seismology

84
00:03:20,530 --> 00:03:18,840
um similarly like on Earth has helped us

85
00:03:23,149 --> 00:03:20,540
to understand more about the actual

86
00:03:25,130 --> 00:03:23,159
interior of Earth

87
00:03:27,770 --> 00:03:25,140
um to like very great detail and so we

88
00:03:31,610 --> 00:03:27,780

hope to be able to do a bit of the same

89
00:03:33,830 --> 00:03:31,620
um on Titan and so some possible causes

90
00:03:36,649 --> 00:03:33,840
of Titan Quakes will be tidal flexing or

91
00:03:38,930 --> 00:03:36,659
Quail volcanoes and then also like ice

92
00:03:40,670 --> 00:03:38,940
cracking events of various kinds and

93
00:03:43,789 --> 00:03:40,680
this is of course not a non-exhaustive

94
00:03:45,410 --> 00:03:43,799
list and so we'll be able to put like

95
00:03:48,289 --> 00:03:45,420
very precise

96
00:03:50,750 --> 00:03:48,299
um more precise hopefully measurements

97
00:03:52,490 --> 00:03:50,760
on what's actually going on there okay

98
00:03:55,789 --> 00:03:52,500
so now this brings me to the namesake of

99
00:03:57,530 --> 00:03:55,799
this talk long period seismology so

100
00:03:59,089 --> 00:03:57,540
um I'm talking about so if you're

101
00:04:00,589 --> 00:03:59,099
familiar with seismograms we have the

102
00:04:02,270 --> 00:04:00,599
Body Waves or those are the p waves

103
00:04:04,369 --> 00:04:02,280
compressive waves and the sheer waves S

104
00:04:06,410 --> 00:04:04,379
waves and then we have

105
00:04:08,630 --> 00:04:06,420
um later on we have these long these

106
00:04:10,009 --> 00:04:08,640
surface waves and so I'm looking as

107
00:04:11,330 --> 00:04:10,019
opposed to using Body Waves

108
00:04:13,610 --> 00:04:11,340
investigating

109
00:04:15,289 --> 00:04:13,620
um and particularly with these I'm

110
00:04:17,689 --> 00:04:15,299
looking at methane cloth rate models

111
00:04:19,849 --> 00:04:17,699
what if I were to use the surface wave

112
00:04:23,570 --> 00:04:19,859
information particularly dispersion

113
00:04:25,370 --> 00:04:23,580

information to be able to try to learn

114
00:04:27,469 --> 00:04:25,380
about Titan and maybe about the

115
00:04:29,390 --> 00:04:27,479
eyeshadow thickness so let's see what I

116
00:04:30,590 --> 00:04:29,400
found okay so starting with methane

117
00:04:33,230 --> 00:04:30,600
clathrates

118
00:04:34,249 --> 00:04:33,240
um I for those of you don't know what

119
00:04:35,930 --> 00:04:34,259
that is

120
00:04:38,570 --> 00:04:35,940
um so a clothway is essentially I like

121
00:04:40,670 --> 00:04:38,580
to say a water cage and so you can see

122
00:04:42,409 --> 00:04:40,680
um I don't know if you can see those

123
00:04:45,170 --> 00:04:42,419
um this is essentially

124
00:04:48,469 --> 00:04:45,180
um a structure of water molecules around

125
00:04:52,670 --> 00:04:48,479
and they're entrapping a single molecule

126
00:04:54,710 --> 00:04:52,680
and and the case of or in my the study

127
00:04:56,990 --> 00:04:54,720
the molecule we're looking at would be

128
00:04:59,330 --> 00:04:57,000
methane okay so imagine there's this

129
00:05:01,850 --> 00:04:59,340
molecule and now we have tens of

130
00:05:03,650 --> 00:05:01,860
kilometers of this these methane

131
00:05:06,469 --> 00:05:03,660
clathrates and we think that this could

132
00:05:09,290 --> 00:05:06,479
be very possible and very plausible for

133
00:05:10,969 --> 00:05:09,300
the Titan for Titan conditions um and I

134
00:05:14,710 --> 00:05:10,979
think I forgot to mention Titan surface

135
00:05:17,390 --> 00:05:14,720
is 94 Kelvin so on the surface methane

136
00:05:19,730 --> 00:05:17,400
we have a hydrological cycle but it's a

137
00:05:21,770 --> 00:05:19,740
methane hydrological cycle

138
00:05:23,930 --> 00:05:21,780

um six percent or five or six percent of

139
00:05:26,150 --> 00:05:23,940
the atmosphere is methane

140
00:05:28,550 --> 00:05:26,160
um and so we have instead of lakes of

141
00:05:30,650 --> 00:05:28,560
water lakes of hydrocarbons

142
00:05:31,370 --> 00:05:30,660
um and lakes of methane

143
00:05:32,689 --> 00:05:31,380
um

144
00:05:34,730 --> 00:05:32,699
so

145
00:05:36,770 --> 00:05:34,740
um when we have this liquid methane and

146
00:05:38,810 --> 00:05:36,780
ice under Titan temperatures and

147
00:05:40,490 --> 00:05:38,820
pressures they will readily form these

148
00:05:42,350 --> 00:05:40,500
methane clathrates and it's been shown

149
00:05:43,730 --> 00:05:42,360
in the laboratory so it's thought that

150
00:05:46,670 --> 00:05:43,740
they're most likely will be lots of

151
00:05:49,550 --> 00:05:46,680
these methane clathrates on Titan

152
00:05:51,650 --> 00:05:49,560
um and so the models that we considered

153
00:05:53,390 --> 00:05:51,660
um were essentially they were all the

154
00:05:56,990 --> 00:05:53,400
same so we were looking at 100 kilometer

155
00:05:59,629 --> 00:05:57,000
thick ice shell and just varying the um

156
00:06:01,430 --> 00:05:59,639
the clathrated lid thickness so um the

157
00:06:03,650 --> 00:06:01,440
cloth grades were just at the surface so

158
00:06:06,050 --> 00:06:03,660
hence the cloth rate lid

159
00:06:07,430 --> 00:06:06,060
um and um yeah these are all spherically

160
00:06:08,810 --> 00:06:07,440
symmetric models they were generated

161
00:06:10,430 --> 00:06:08,820
with an open source code called Planet

162
00:06:12,950 --> 00:06:10,440
profile if you're interested in

163
00:06:14,390 --> 00:06:12,960

generating this it's on GitHub also you

164
00:06:16,430 --> 00:06:14,400
can I couldn't show you how to get it or

165
00:06:19,070 --> 00:06:16,440
you can just Google it

166
00:06:21,710 --> 00:06:19,080
um and there's a ton of other bodies you

167
00:06:23,990 --> 00:06:21,720
can look at there as well and so we

168
00:06:26,029 --> 00:06:24,000
simulated a magnitude 3 quick and then

169
00:06:28,370 --> 00:06:26,039
these were the data that we'll be

170
00:06:29,870 --> 00:06:28,380
looking at come from a three kilometer

171
00:06:32,510 --> 00:06:29,880
Source step so three kilometers deep

172
00:06:34,670 --> 00:06:32,520
within the ice

173
00:06:37,370 --> 00:06:34,680
Okay so so um

174
00:06:41,270 --> 00:06:37,380
the from the study

175
00:06:42,710 --> 00:06:41,280
um I this was led by Angela marusiak at

176
00:06:45,230 --> 00:06:42,720
um who is now professor at University of

177
00:06:46,909 --> 00:06:45,240
Arizona uh and so we actually saw some

178
00:06:48,590 --> 00:06:46,919
small differences in dispersion between

179
00:06:50,629 --> 00:06:48,600
two of the models in particular that

180
00:06:52,189 --> 00:06:50,639
we're looking at and in that paper so

181
00:06:53,749 --> 00:06:52,199
that was the 10 kilometer cloth rate lid

182
00:06:57,469 --> 00:06:53,759
and the

183
00:07:00,170 --> 00:06:57,479
um pure water is shell and so just for

184
00:07:01,610 --> 00:07:00,180
this is a primer about dispersion it's

185
00:07:03,469 --> 00:07:01,620
related to the material properties of

186
00:07:05,210 --> 00:07:03,479
the ice shell and particularly in the

187
00:07:07,850 --> 00:07:05,220
case of elastic waves that we're looking

188
00:07:09,170 --> 00:07:07,860

at here and so this wave speed depends

189
00:07:11,210 --> 00:07:09,180
on frequency and that's kind of like the

190
00:07:13,629 --> 00:07:11,220
meat of what dispersion is is seeing how

191
00:07:15,890 --> 00:07:13,639
the wave speed or the group velocities

192
00:07:18,050 --> 00:07:15,900
they change as a function of frequency

193
00:07:19,850 --> 00:07:18,060
and so we saw like about two percent

194
00:07:22,070 --> 00:07:19,860
difference a two percent difference

195
00:07:24,409 --> 00:07:22,080
between the dispersion so that's looking

196
00:07:26,689 --> 00:07:24,419
at this group velocity curve here it's

197
00:07:27,950 --> 00:07:26,699
very small differences but they're small

198
00:07:29,689 --> 00:07:27,960
enough that if you have a really high

199
00:07:31,550 --> 00:07:29,699
Precision seismometer you could actually

200
00:07:33,170 --> 00:07:31,560
detect that which is actually I found

201
00:07:35,210 --> 00:07:33,180
that quite intriguing so I was like well

202
00:07:36,290 --> 00:07:35,220
let's dig deeper and see what else we

203
00:07:39,770 --> 00:07:36,300
can find

204
00:07:42,589 --> 00:07:39,780
um so this brings me to the setup of the

205
00:07:44,870 --> 00:07:42,599
um on the project of this long period

206
00:07:47,390 --> 00:07:44,880
study that I'm leading now so

207
00:07:49,129 --> 00:07:47,400
um I take theoretical dispersion curves

208
00:07:50,990 --> 00:07:49,139
so it's all theoretical but these are

209
00:07:52,610 --> 00:07:51,000
extra theoretical

210
00:07:53,689 --> 00:07:52,620
um and I can explain what that means

211
00:07:55,610 --> 00:07:53,699
later

212
00:07:57,290 --> 00:07:55,620
um or if you if you ask um so

213
00:07:59,809 --> 00:07:57,300

theoretical this version curve they're

214
00:08:02,270 --> 00:07:59,819
generated with a code called mineos and

215
00:08:05,089 --> 00:08:02,280
elaborate on that and then take these

216
00:08:07,550 --> 00:08:05,099
other axi Simmons it says that's another

217
00:08:08,570 --> 00:08:07,560
code so the different methods of doing

218
00:08:10,969 --> 00:08:08,580
these things

219
00:08:12,710 --> 00:08:10,979
um seismograms to create these mock

220
00:08:15,650 --> 00:08:12,720
observational data of which I would go

221
00:08:17,390 --> 00:08:15,660
and pick and calculate by hand

222
00:08:19,909 --> 00:08:17,400
um and with a computer the group

223
00:08:22,309 --> 00:08:19,919
velocities for each Titan input model

224
00:08:24,950 --> 00:08:22,319
I'm not sure that I'm across a range of

225
00:08:26,990 --> 00:08:24,960
distances um and frequencies so

226
00:08:29,689 --> 00:08:27,000
um now just I'll talk about the

227
00:08:32,630 --> 00:08:29,699
theoretical group velocities

228
00:08:35,149 --> 00:08:32,640
um and so these are looking at group

229
00:08:37,250 --> 00:08:35,159
velocity as a functional frequency so

230
00:08:38,810 --> 00:08:37,260
group velocity on the y-axis and

231
00:08:40,370 --> 00:08:38,820
frequency on the X axes and I'm looking

232
00:08:41,690 --> 00:08:40,380
at different modes so I'll talk about

233
00:08:43,430 --> 00:08:41,700
what the screw velocities and phase

234
00:08:46,010 --> 00:08:43,440
velocities are and or group velocities

235
00:08:47,570 --> 00:08:46,020
are and then what the modes are

236
00:08:49,009 --> 00:08:47,580
um so group velocity

237
00:08:51,230 --> 00:08:49,019
um if we were to look if you look on the

238
00:08:53,990 --> 00:08:51,240

right hand side it's

239
00:08:56,810 --> 00:08:54,000
um the the actual velocity of the like

240
00:08:58,730 --> 00:08:56,820
wave packet that's encapsulating the

241
00:09:01,009 --> 00:08:58,740
like more the bigger larger scale

242
00:09:02,870 --> 00:09:01,019
structure of our seismograms and the

243
00:09:04,490 --> 00:09:02,880
phase velocities that's another measure

244
00:09:08,150 --> 00:09:04,500
of dispersion

245
00:09:10,250 --> 00:09:08,160
um it is the actual velocity of the

246
00:09:11,810 --> 00:09:10,260
Peaks and so when you have the groove

247
00:09:14,389 --> 00:09:11,820
velocity not equal to the phase velocity

248
00:09:16,009 --> 00:09:14,399
you you know you have a dispersive wave

249
00:09:16,730 --> 00:09:16,019
um and so

250
00:09:20,329 --> 00:09:16,740
um

251
00:09:22,009 --> 00:09:20,339
the terminal information so mode so if

252
00:09:24,470 --> 00:09:22,019
if you remember from physics the like

253
00:09:27,110 --> 00:09:24,480
wave on the string analogy

254
00:09:28,910 --> 00:09:27,120
um or it's not analogy but the wave on a

255
00:09:30,710 --> 00:09:28,920
string representation of modes

256
00:09:33,170 --> 00:09:30,720
um the fundamental modes will be here

257
00:09:35,990 --> 00:09:33,180
there's no node first overturn one node

258
00:09:38,630 --> 00:09:36,000
second third second and two and three

259
00:09:40,190 --> 00:09:38,640
nodes uh accordingly or respectively and

260
00:09:43,250 --> 00:09:40,200
then you can go all the way up to I mean

261
00:09:44,810 --> 00:09:43,260
as many nodes and modes as you'd like to

262
00:09:47,810 --> 00:09:44,820
um so for this study we actually looked

263
00:09:50,990 --> 00:09:47,820

at up to three thousand uh overtones to

264
00:09:52,490 --> 00:09:51,000
create an entire seismogram but here

265
00:09:54,650 --> 00:09:52,500
um we know that most of the information

266
00:09:56,449 --> 00:09:54,660
of this surface wave that we're looking

267
00:09:57,949 --> 00:09:56,459
at and I forgot to mention that it's a

268
00:10:01,490 --> 00:09:57,959
Rayleigh wave

269
00:10:03,769 --> 00:10:01,500
um it was it would normally be in the

270
00:10:05,329 --> 00:10:03,779
fundamental mode but

271
00:10:07,130 --> 00:10:05,339
um there's a surprise that I'll show you

272
00:10:07,790 --> 00:10:07,140
in the next slide

273
00:10:10,550 --> 00:10:07,800
um

274
00:10:13,970 --> 00:10:10,560
and so essentially what we found was

275
00:10:15,949 --> 00:10:13,980
that when we're comparing

276
00:10:18,470 --> 00:10:15,959
um when we're looking at the data and I

277
00:10:19,670 --> 00:10:18,480
I went and used actually some this other

278
00:10:21,410 --> 00:10:19,680
data set

279
00:10:22,550 --> 00:10:21,420
um and took the seismograms themselves

280
00:10:23,990 --> 00:10:22,560
and

281
00:10:25,430 --> 00:10:24,000
um calculated the group velocities as

282
00:10:27,590 --> 00:10:25,440
opposed to just them being spit out from

283
00:10:29,930 --> 00:10:27,600
a code for me

284
00:10:32,690 --> 00:10:29,940
um consistently that

285
00:10:33,710 --> 00:10:32,700
um the dispersion profiles um there when

286
00:10:36,050 --> 00:10:33,720
we look at the different interior

287
00:10:37,730 --> 00:10:36,060
structures they do like differ slightly

288
00:10:39,530 --> 00:10:37,740

but then when we lay them on top of each

289
00:10:41,509 --> 00:10:39,540
other essentially like there isn't

290
00:10:43,430 --> 00:10:41,519
various little differences and it's so

291
00:10:44,690 --> 00:10:43,440
small that you probably would not and

292
00:10:47,110 --> 00:10:44,700
not probably wouldn't they would be

293
00:10:49,430 --> 00:10:47,120
smaller than what we could observe

294
00:10:52,069 --> 00:10:49,440
on Titan

295
00:10:53,750 --> 00:10:52,079
um so and then also the Israeli waves we

296
00:10:55,190 --> 00:10:53,760
thought that they would be the

297
00:10:56,870 --> 00:10:55,200
information would be in the fundamental

298
00:10:58,730 --> 00:10:56,880
mode but actually it was in the first

299
00:11:00,769 --> 00:10:58,740
overtone which is a little interesting

300
00:11:02,449 --> 00:11:00,779
and it's consistently so that okay so

301
00:11:05,090 --> 00:11:02,459
there's this yellow line is the first

302
00:11:07,910 --> 00:11:05,100
overtone and so this blue little Cloud

303
00:11:09,829 --> 00:11:07,920
thing is the one Sigma standard

304
00:11:12,410 --> 00:11:09,839
deviation from these group velocity

305
00:11:15,590 --> 00:11:12,420
measurements which are taken over a

306
00:11:18,110 --> 00:11:15,600
range of just instances and frequencies

307
00:11:20,630 --> 00:11:18,120
um and so

308
00:11:22,970 --> 00:11:20,640
um yeah it's it's a pretty pretty strong

309
00:11:25,790 --> 00:11:22,980
uh thing that's happening or signal that

310
00:11:27,230 --> 00:11:25,800
we're seeing for it not being and the

311
00:11:29,630 --> 00:11:27,240
fundamental mode

312
00:11:30,590 --> 00:11:29,640
um and so then that just shows that this

313
00:11:33,530 --> 00:11:30,600

method

314
00:11:34,610 --> 00:11:33,540
um we wouldn't be able to use Body Waves

315
00:11:37,430 --> 00:11:34,620
to

316
00:11:39,470 --> 00:11:37,440
um this sorry the surface wave this

317
00:11:41,210 --> 00:11:39,480
particular surface wave as

318
00:11:44,930 --> 00:11:41,220
um to diagnose the thickness of Titan's

319
00:11:49,550 --> 00:11:44,940
eyeshadow so that's intriguing and so

320
00:11:52,190 --> 00:11:49,560
um I will dig deeper and and see

321
00:11:53,810 --> 00:11:52,200
um more about that in the future all

322
00:11:55,850 --> 00:11:53,820
right so a quick summary I use data

323
00:11:57,710 --> 00:11:55,860
driven models of Titan's Interiors or to

324
00:11:59,690 --> 00:11:57,720
compute Titan synthetic seismograms for

325
00:12:01,970 --> 00:11:59,700
comparison to real data that we'll get

326
00:12:03,769 --> 00:12:01,980
from dragonfly in the mid-2030s and in

327
00:12:05,090 --> 00:12:03,779
the study we investigate energy chat

328
00:12:07,069 --> 00:12:05,100
trapped in the eye shell to determine

329
00:12:09,350 --> 00:12:07,079
the structure of Titan and the presence

330
00:12:11,810 --> 00:12:09,360
of surface clathrates

331
00:12:14,269 --> 00:12:11,820
um and AKA long period seismology And

332
00:12:15,590 --> 00:12:14,279
while the surface waves observation that

333
00:12:18,050 --> 00:12:15,600
we saw in the study do not clearly

334
00:12:20,210 --> 00:12:18,060
determine thickness we can constrain it

335
00:12:21,230 --> 00:12:20,220
using body wave arrivals so P and S

336
00:12:22,970 --> 00:12:21,240
waves and if you're interested in

337
00:12:24,829 --> 00:12:22,980
learning more about isolation seismology

338
00:12:27,410 --> 00:12:24,839

and particularly about some of the

339
00:12:29,449 --> 00:12:27,420
methodology that we were implementing

340
00:12:32,930 --> 00:12:29,459
talk to me or also consult Simon

341
00:12:35,630 --> 00:12:32,940
staler's paper uh it's very looking also

342
00:12:37,670 --> 00:12:35,640
at other icy ocean worlds as well and

343
00:12:39,410 --> 00:12:37,680
then understanding the composition of

344
00:12:40,910 --> 00:12:39,420
Titan's interior especially the ice

345
00:12:43,129 --> 00:12:40,920
shell and ocean will have important

346
00:12:45,230 --> 00:12:43,139
implications for astrobiology and

347
00:12:50,730 --> 00:12:45,240
habitability studies so thank you so

348
00:12:50,740 --> 00:13:03,290
[Music]

349
00:13:10,970 --> 00:13:05,509
all right

350
00:13:15,949 --> 00:13:13,129
hi nice talk

351
00:13:16,910 --> 00:13:15,959
um so presumably like in the lab we

352
00:13:19,250 --> 00:13:16,920
don't have

353
00:13:21,889 --> 00:13:19,260
like kilometers of class rates so what

354
00:13:25,069 --> 00:13:21,899
does it take to extrapolate from just

355
00:13:26,870 --> 00:13:25,079
this lab made amount to how it'll behave

356
00:13:29,569 --> 00:13:26,880
when it's this much

357
00:13:32,569 --> 00:13:29,579
um as a medium yeah so we use this paper

358
00:13:34,509 --> 00:13:32,579
called by calasova and soton I think

359
00:13:36,230 --> 00:13:34,519
it's in like 20

360
00:13:38,509 --> 00:13:36,240
20.

361
00:13:39,949 --> 00:13:38,519
um but that was their paper is where we

362
00:13:42,350 --> 00:13:39,959
got the actual thermal

363
00:13:54,530 --> 00:13:42,360

um thermal models to model to model this

364
00:13:57,949 --> 00:13:56,150
thank you for the talk

365
00:14:01,310 --> 00:13:57,959
um I I have a question that may be

366
00:14:03,290 --> 00:14:01,320
outside of the scope of what you do but

367
00:14:06,290 --> 00:14:03,300
um I know that the eye shelf thickness

368
00:14:10,310 --> 00:14:06,300
can be a proxy for for heat loss and

369
00:14:12,650 --> 00:14:10,320
that can also kind of um uh

370
00:14:14,690 --> 00:14:12,660
provide clues as to whether the ocean

371
00:14:17,030 --> 00:14:14,700
may be like a transient feature like a

372
00:14:19,430 --> 00:14:17,040
more long-lived feature is that anything

373
00:14:21,069 --> 00:14:19,440
you can determine using the data that

374
00:14:23,750 --> 00:14:21,079
may be

375
00:14:25,610 --> 00:14:23,760
collected by dragonfly or anything like

376
00:14:28,310 --> 00:14:25,620
that or is that outside of the scope of

377
00:14:30,590 --> 00:14:28,320
because I mean the the longevity of the

378
00:14:32,150 --> 00:14:30,600
ocean like if there is like a like a

379
00:14:34,009 --> 00:14:32,160
liquid water ocean

380
00:14:35,449 --> 00:14:34,019
um beneath the ice layers that could

381
00:14:36,949 --> 00:14:35,459
have implications in the habitability

382
00:14:38,990 --> 00:14:36,959
whether it's like persisted over

383
00:14:43,189 --> 00:14:39,000
geologic time scales

384
00:14:45,889 --> 00:14:43,199
yeah I mean I mean we can constrain the

385
00:14:50,030 --> 00:14:45,899
with just what size seismology the

386
00:14:51,530 --> 00:14:50,040
composition and the depth but regarding

387
00:15:03,170 --> 00:14:51,540
yeah it's a little bit outside of my

388
00:15:05,990 --> 00:15:05,269

yeah uh so I'm curious

389
00:15:07,910 --> 00:15:06,000
um

390
00:15:09,650 --> 00:15:07,920
what is the amount of confidence we have

391
00:15:11,810 --> 00:15:09,660
that there's a high pressure ice layer

392
00:15:14,389 --> 00:15:11,820
on the bottom instead of you know a

393
00:15:16,850 --> 00:15:14,399
direct contact with the ocean yeah I

394
00:15:19,310 --> 00:15:16,860
mean we don't have like any confidence

395
00:15:21,530 --> 00:15:19,320
to say I mean

396
00:15:22,910 --> 00:15:21,540
um we think that there could be

397
00:15:27,050 --> 00:15:22,920
um I think there's

398
00:15:29,030 --> 00:15:27,060
definitely a big Camp thinking there is

399
00:15:31,670 --> 00:15:29,040
um but it's highly debatable so if I

400
00:15:33,829 --> 00:15:31,680
were to like look at that diagram

401
00:15:34,910 --> 00:15:33,839
um I could put a big sorry going way

402
00:15:37,490 --> 00:15:34,920
back

403
00:15:38,810 --> 00:15:37,500
um there

404
00:15:40,129 --> 00:15:38,820
um for the high pressure eyes you could

405
00:15:42,050 --> 00:15:40,139
put like a big question mark there

406
00:15:43,370 --> 00:15:42,060
because we don't know if it's there we

407
00:15:45,170 --> 00:15:43,380
don't know how thick it is it's like

408
00:15:48,410 --> 00:15:45,180
really deep down we know there's no

409
00:15:50,329 --> 00:15:48,420
molten core in Titan from some Casini

410
00:15:52,009 --> 00:15:50,339
measurements but high pressure rise we

411
00:15:54,650 --> 00:15:52,019
have a zero idea

412
00:15:56,449 --> 00:15:54,660
um but it could be there

413
00:15:57,889 --> 00:15:56,459

um and so especially because it's so

414
00:16:00,350 --> 00:15:57,899
cold but then

415
00:16:02,269 --> 00:16:00,360
yeah and if it is there there's

416
00:16:04,069 --> 00:16:02,279
different scenarios also that if we have

417
00:16:06,410 --> 00:16:04,079
porous high pressure eyes and it's

418
00:16:07,550 --> 00:16:06,420
really saline and then it could still

419
00:16:09,170 --> 00:16:07,560
um we could still have some enrichment

420
00:16:11,389 --> 00:16:09,180
of the ocean so even if it is there

421
00:16:13,370 --> 00:16:11,399
depending on its composition they could

422
00:16:15,350 --> 00:16:13,380
still be enrichment of the ocean

423
00:16:18,530 --> 00:16:15,360
um so it may not necessarily be a

424
00:16:32,569 --> 00:16:18,540
barrier to life also if it is there

425
00:16:37,249 --> 00:16:35,329
hi nice talk I would like to ask you if

426
00:16:39,889 --> 00:16:37,259
you have considered the influenza of the

427
00:16:41,810 --> 00:16:39,899
titleistic patient in your models always

428
00:16:43,970 --> 00:16:41,820
the title dissipation

429
00:16:45,829 --> 00:16:43,980
oh do I incorporate that if you have

430
00:16:48,170 --> 00:16:45,839
considered that influence in the

431
00:16:50,509 --> 00:16:48,180
generation of a Titan earthquake Titan

432
00:16:53,090 --> 00:16:50,519
Quake sorry so have you considered the

433
00:16:54,650 --> 00:16:53,100
influenza of the tidal dissipation

434
00:16:56,030 --> 00:16:54,660
um no we're not considering tidal

435
00:16:58,430 --> 00:16:56,040
dissipation

436
00:17:01,249 --> 00:16:58,440
um in the models or we're assuming it's

437
00:17:02,870 --> 00:17:01,259
a very perfect Titan but I also don't

438
00:17:04,309 --> 00:17:02,880

think

439
00:17:07,429 --> 00:17:04,319
um we're assuming we're considering

440
00:17:10,789 --> 00:17:07,439
attenuation within the ice shell but

441
00:17:14,710 --> 00:17:13,130
um we're not really thinking about I

442
00:17:19,329 --> 00:17:14,720
think and I don't think we need to yeah

443
00:17:26,090 --> 00:17:23,270
about earthquake if you

444
00:17:28,549 --> 00:17:26,100
um synthesize the sex meet analysis and

445
00:17:31,490 --> 00:17:28,559
the influencing of the television so um

446
00:17:34,669 --> 00:17:31,500
I don't know how much is a contribution

447
00:17:37,789 --> 00:17:34,679
of the Titan so that's why I am asking

448
00:17:39,529 --> 00:17:37,799
you if you have considered this um we

449
00:17:49,150 --> 00:17:39,539
haven't considered this parameter in

450
00:17:53,930 --> 00:17:52,789
yeah I don't know if it has like a huge

451
00:17:55,909 --> 00:17:53,940
um

452
00:17:58,549 --> 00:17:55,919
so so the title

453
00:18:00,650 --> 00:17:58,559
I don't think I will have uh like a

454
00:18:03,169 --> 00:18:00,660
large effect which is why we've left it

455
00:18:05,210 --> 00:18:03,179
out yeah yeah also that bang of the

456
00:18:07,190 --> 00:18:05,220
distance between the Titan and sat or so

457
00:18:12,650 --> 00:18:07,200
yeah I don't know that's why I was

458
00:18:18,890 --> 00:18:15,289
one more question

459
00:18:21,890 --> 00:18:18,900
so uh um I'm not a planetary geologist

460
00:18:23,270 --> 00:18:21,900
but I I do know that one of the

461
00:18:24,770 --> 00:18:23,280
limitations for our understanding of the

462
00:18:26,810 --> 00:18:24,780
interior of Mars with the Insight

463
00:18:28,789 --> 00:18:26,820

mission was that we only had a single

464
00:18:31,549 --> 00:18:28,799
seismometer yeah

465
00:18:33,650 --> 00:18:31,559
um in your data are you modeling uh

466
00:18:35,570 --> 00:18:33,660
basically seismology

467
00:18:37,730 --> 00:18:35,580
being measured by a single seismometer

468
00:18:39,350 --> 00:18:37,740
and you think having multiple

469
00:18:41,390 --> 00:18:39,360
seismometers on the surface of Titan

470
00:18:42,890 --> 00:18:41,400
would give you further resolution in

471
00:18:44,630 --> 00:18:42,900
terms of the thickness of methane

472
00:18:48,529 --> 00:18:44,640
clathrate lid

473
00:18:52,430 --> 00:18:48,539
yeah 100 it would be amazing to have

474
00:18:54,770 --> 00:18:52,440
multiple seismometers on Mars also on

475
00:18:56,750 --> 00:18:54,780
Titan but I think just with experimental

476
00:18:59,990 --> 00:18:56,760
Mission constraints like they can only

477
00:19:02,270 --> 00:19:00,000
have one have you done any modeling to

478
00:19:05,510 --> 00:19:02,280
see if you could get further resolution

479
00:19:07,190 --> 00:19:05,520
with multiple seismometers

480
00:19:10,370 --> 00:19:07,200
um so it's not so it's not really about

481
00:19:11,810 --> 00:19:10,380
like getting the resolution with

482
00:19:13,610 --> 00:19:11,820
um so we can generate perfect

483
00:19:16,130 --> 00:19:13,620
seismograms

484
00:19:18,770 --> 00:19:16,140
um it's just how well we'll be able to

485
00:19:20,990 --> 00:19:18,780
see and detect

486
00:19:23,270 --> 00:19:21,000
um things I see it's easier to like

487
00:19:26,029 --> 00:19:23,280
triangulate events and things with um

488
00:19:29,150 --> 00:19:26,039

when you have multiple seismometers

489
00:19:31,310 --> 00:19:29,160
um but yeah we can essentially if we we

490
00:19:33,529 --> 00:19:31,320
could see like deeper events if we have

491
00:19:35,510 --> 00:19:33,539
more seismometers we'd have just greater

492
00:19:38,150 --> 00:19:35,520
sensitivity overall

493
00:19:40,669 --> 00:19:38,160
um but we unfortunately don't have that

494
00:19:44,330 --> 00:19:40,679
yeah so we have to do what we can with

495
00:19:44,340 --> 00:19:50,380
thank you Andrea yeah

496
00:19:53,890 --> 00:19:51,610
[Music]