
AbSciCon
2019

1
00:00:00,790 --> 00:00:07,320
[Music]

2
00:00:12,740 --> 00:00:09,250
[Applause]

3
00:00:16,580 --> 00:00:12,750
Thank You per se and please stick around

4
00:00:20,330 --> 00:00:16,590
for the discussion after my talk so I

5
00:00:23,570 --> 00:00:20,340
want to kind of talk about salts and

6
00:00:25,730 --> 00:00:23,580
wrap them up across the solar system so

7
00:00:29,090 --> 00:00:25,740
this morning we had a discussion about

8
00:00:31,130 --> 00:00:29,100
brines predominantly here on earth and

9
00:00:33,560 --> 00:00:31,140
habitability there we talked a lot about

10
00:00:36,290 --> 00:00:33,570
Mars in this session I will also talk

11
00:00:39,740 --> 00:00:36,300
about Mars but also thinking into

12
00:00:42,610 --> 00:00:39,750
further in across the solar system so

13
00:00:46,130 --> 00:00:42,620

here I have two images on the left is

14
00:00:48,619 --> 00:00:46,140
Columbus crater on Mars and it's one of

15
00:00:53,060 --> 00:00:48,629
these great Paleo Lake examples you can

16
00:00:55,520 --> 00:00:53,070
even see the salt ring deposited as a

17
00:00:56,840 --> 00:00:55,530
bathtub ring as it evaporated and then

18
00:01:00,200 --> 00:00:56,850
on the right you wrote by which I'll

19
00:01:02,329 --> 00:01:00,210
talk a little bit about as well so first

20
00:01:04,340 --> 00:01:02,339
very briefly if you're in this session

21
00:01:07,100 --> 00:01:04,350
you probably know about salts but

22
00:01:10,520 --> 00:01:07,110
chlorine salts in particular have a wide

23
00:01:13,550 --> 00:01:10,530
variety of flavors we have chlorides

24
00:01:17,029 --> 00:01:13,560
which is just CL minus all the way up to

25
00:01:20,060 --> 00:01:17,039
the highly oxidated perchlorate CLO 4

26
00:01:24,260 --> 00:01:20,070
I'll just note that hypochlorite that's

27
00:01:28,010 --> 00:01:24,270
bleach NaCl o is bleach chlorite these

28
00:01:29,630 --> 00:01:28,020
are both very they're not very stable so

29
00:01:31,789 --> 00:01:29,640
they're mostly intermediate processes

30
00:01:34,459 --> 00:01:31,799
into the formation of chlorate and

31
00:01:36,770 --> 00:01:34,469
perchlorate which are fairly equally

32
00:01:38,779 --> 00:01:36,780
stable so during formation you end up

33
00:01:41,539 --> 00:01:38,789
with both chlorate and perchlorate in

34
00:01:42,919 --> 00:01:41,549
about equal amounts everywhere you find

35
00:01:45,709 --> 00:01:42,929
one you find the other and just about

36
00:01:47,090 --> 00:01:45,719
equal amounts so the things the three

37
00:01:49,399 --> 00:01:47,100
cells that were most interested in are

38
00:01:52,160 --> 00:01:49,409

going to be chlorides chlorates

39
00:01:53,389 --> 00:01:52,170
and perchlorates and the reason that

40
00:01:55,639 --> 00:01:53,399
it's really important to distinguish

41
00:01:56,929 --> 00:01:55,649
between the different types of chlorine

42
00:02:00,020 --> 00:01:56,939
salts and the different types of salts

43
00:02:01,880 --> 00:02:00,030
in general is because they all have a

44
00:02:04,399 --> 00:02:01,890
different effect on the activity of

45
00:02:06,830 --> 00:02:04,409
water freezing point and just the

46
00:02:09,590 --> 00:02:06,840
general stability and habitability so

47
00:02:11,600 --> 00:02:09,600
here you can see a table of different

48
00:02:15,770 --> 00:02:11,610
salts and their eutectic temperatures

49
00:02:18,259 --> 00:02:15,780
which is just one of many things that

50
00:02:20,899 --> 00:02:18,269
affect habitability but obviously when

51
00:02:22,520 --> 00:02:20,909
we start talking about the solar system

52
00:02:24,950 --> 00:02:22,530
getting to temperatures where

53
00:02:29,180 --> 00:02:24,960
water can exist that's kind of you know

54
00:02:30,860 --> 00:02:29,190
step zero step one and sulfates and

55
00:02:33,560 --> 00:02:30,870
carbonates which have been the

56
00:02:34,700 --> 00:02:33,570
predominant salts found across the solar

57
00:02:37,220 --> 00:02:34,710
system on Mars

58
00:02:39,260 --> 00:02:37,230
Europa they don't lower the freezing

59
00:02:41,870 --> 00:02:39,270
point as much as chlorine salts do and

60
00:02:43,610 --> 00:02:41,880
you can see here as has been much talked

61
00:02:45,350 --> 00:02:43,620
about in this session calcium

62
00:02:47,900 --> 00:02:45,360
perchlorate down here at the very bottom

63
00:02:50,360 --> 00:02:47,910

at 198 Kelvin but you can see even some

64
00:02:54,199 --> 00:02:50,370
of the other magnesium chlorate and

65
00:02:56,420 --> 00:02:54,209
perchlorate calcium chloride etc going

66
00:02:59,780 --> 00:02:56,430
up here my knees iam sulfate a much

67
00:03:03,140 --> 00:02:59,790
favored salt on both Mars and Europe a

68
00:03:06,590 --> 00:03:03,150
seen in a lot of places it only lowers

69
00:03:08,270 --> 00:03:06,600
it by four so it's not as it doesn't

70
00:03:10,400 --> 00:03:08,280
extend the stability range as much as

71
00:03:11,900 --> 00:03:10,410
some of the other chlorine salts and

72
00:03:15,080 --> 00:03:11,910
then of course chlorine salts can also

73
00:03:17,420 --> 00:03:15,090
be a source of energy here's just a

74
00:03:20,449 --> 00:03:17,430
diagram to kind of visually represent

75
00:03:24,620 --> 00:03:20,459
this so of course on earth we have pure

76
00:03:28,220 --> 00:03:24,630
liquid water freezes at zero C it boils

77
00:03:33,440 --> 00:03:28,230
at 100 unless you live in Flagstaff I do

78
00:03:36,289 --> 00:03:33,450
and then I boils at 93 Celsius and this

79
00:03:38,360 --> 00:03:36,299
is exactly why the stability on Mars is

80
00:03:39,860 --> 00:03:38,370
so reduced because the boiling point is

81
00:03:42,890 --> 00:03:39,870
dependent on pressure ya mysteric

82
00:03:46,250 --> 00:03:42,900
pressure and so on Mars the sir the

83
00:03:48,949 --> 00:03:46,260
boiling point is only 10 C however if

84
00:03:51,259 --> 00:03:48,959
you look at a saturated a eutectic

85
00:03:52,670 --> 00:03:51,269
composition of magnesium perchlorate you

86
00:03:55,430 --> 00:03:52,680
can get freezing temperatures down to

87
00:03:57,920 --> 00:03:55,440
minus 67 Celsius and you actually also

88
00:04:01,280 --> 00:03:57,930

extend the boiling temperature up to 24

89
00:04:03,350 --> 00:04:01,290
C so you're really extending the range

90
00:04:07,520 --> 00:04:03,360
of stability in both directions for

91
00:04:08,960 --> 00:04:07,530
temperature and just for comparison this

92
00:04:12,229 --> 00:04:08,970
would be like magnesium sulfate it

93
00:04:15,319 --> 00:04:12,239
doesn't extend the the boiling point at

94
00:04:19,580 --> 00:04:15,329
all and as I mentioned only four degrees

95
00:04:23,090 --> 00:04:19,590
below pure so another example of why

96
00:04:24,530 --> 00:04:23,100
salts are so cool is this deliquescent

97
00:04:28,010 --> 00:04:24,540
thing that everyone's been talking about

98
00:04:30,080 --> 00:04:28,020
so here's a video of it this was taken

99
00:04:32,570 --> 00:04:30,090
in a chamber at the University of

100
00:04:36,619 --> 00:04:32,580
Arkansas and this is magnesium

101
00:04:39,409 --> 00:04:36,629
perchlorate you can see it's actually

102
00:04:42,619 --> 00:04:39,419
you know fairly humid it's fairly warm

103
00:04:44,809 --> 00:04:42,629
and I will note this is an 18 hour time

104
00:04:47,450 --> 00:04:44,819
lapse so as we start over from the

105
00:04:50,899 --> 00:04:47,460
beginning you can see that the droplets

106
00:04:53,510 --> 00:04:50,909
start to form almost immediately but it

107
00:04:55,820 --> 00:04:53,520
does take over the course of 18 hours

108
00:04:58,390 --> 00:04:55,830
you still don't have all of it

109
00:05:00,589 --> 00:04:58,400
deliquescent and this is at a very high

110
00:05:03,260 --> 00:05:00,599
much higher than the deliquescent

111
00:05:04,520 --> 00:05:03,270
relative humidity that we've seen in

112
00:05:06,730 --> 00:05:04,530
some of these other talks in a much

113
00:05:09,439 --> 00:05:06,740

warmer temperature so even at these

114
00:05:12,140 --> 00:05:09,449
relatively benign conditions it still

115
00:05:16,850 --> 00:05:12,150
takes almost a day for the majority of

116
00:05:19,189 --> 00:05:16,860
the salt to Delic west so thinking about

117
00:05:22,300 --> 00:05:19,199
whether life can even utilize these

118
00:05:25,969 --> 00:05:22,310
salts or tolerate you know there's been

119
00:05:28,850 --> 00:05:25,979
a lot of discussion in the earth

120
00:05:30,439 --> 00:05:28,860
community about that microbial community

121
00:05:33,019 --> 00:05:30,449
has been found to thrive and my knees

122
00:05:38,839 --> 00:05:33,029
and chloride rich brines this was down

123
00:05:42,260 --> 00:05:38,849
to an activity of 0.63 I will note that

124
00:05:43,969 --> 00:05:42,270
they found sodium and this whole fate in

125
00:05:46,339 --> 00:05:43,979
there as well so that could have a

126
00:05:49,219 --> 00:05:46,349
mediating effect on this magnesium

127
00:05:51,230 --> 00:05:49,229
chloride so again activity is not the

128
00:05:52,939 --> 00:05:51,240
end-all be-all determination for

129
00:05:57,230 --> 00:05:52,949
habitability of the brines

130
00:06:00,589 --> 00:05:57,240
but still having them you know seeing

131
00:06:03,369 --> 00:06:00,599
where we can extend the limits we've

132
00:06:09,019 --> 00:06:03,379
seen bacteria metabolize down to 18%

133
00:06:12,529 --> 00:06:09,029
NaCl and - 25 C and then one of the my

134
00:06:14,829 --> 00:06:12,539
favorite stories stories telling this

135
00:06:22,670 --> 00:06:14,839
picture here is hey light crusts and so

136
00:06:25,279 --> 00:06:22,680
this Davila at all 2008 one here

137
00:06:27,860 --> 00:06:25,289
went to the Atacama Desert and measured

138
00:06:29,570 --> 00:06:27,870

basically how many times it rained in a

139
00:06:32,809 --> 00:06:29,580
year and they found that it rained once

140
00:06:35,600 --> 00:06:32,819
and so that's about six hours total of

141
00:06:36,860 --> 00:06:35,610
liquid water event however in these

142
00:06:38,480 --> 00:06:36,870
halite crystals

143
00:06:41,629 --> 00:06:38,490
we've talked a lot about deliquescent

144
00:06:43,730 --> 00:06:41,639
this is just NaCl the relative humidity

145
00:06:45,350 --> 00:06:43,740
the deliquescent relative humidity is 75

146
00:06:49,830 --> 00:06:45,360
percent so the amount of times that it

147
00:06:54,290 --> 00:06:49,840
crossed 75 percent relative mini was 57

148
00:06:57,750 --> 00:06:54,300
so 57 events where there it was liquid

149
00:07:00,450 --> 00:06:57,760
inside these hey light crusts for the

150
00:07:05,280 --> 00:07:00,460
microbes to utilize that water versus

151
00:07:08,070 --> 00:07:05,290
one event of rainfall outside of it and

152
00:07:11,700 --> 00:07:08,080
then there's examples of perchlorate and

153
00:07:14,960 --> 00:07:11,710
chlorate reducing bacteria so chlorine

154
00:07:17,520 --> 00:07:14,970
salts are pretty interesting and

155
00:07:20,340 --> 00:07:17,530
potentially tolerable to some sorts of

156
00:07:22,830 --> 00:07:20,350
life so where have these chlorine salts

157
00:07:24,120 --> 00:07:22,840
been found in particular perchlorates so

158
00:07:26,190 --> 00:07:24,130
they've been measured by the Phoenix

159
00:07:29,060 --> 00:07:26,200
mission by the wet chemistry lab and

160
00:07:32,970 --> 00:07:29,070
then in Gale Crater by curiosity on

161
00:07:35,190 --> 00:07:32,980
earth as mentioned they are pretty rare

162
00:07:37,320 --> 00:07:35,200
in fact accumulating only in these hyper

163
00:07:40,260 --> 00:07:37,330

arid environments like the Antarctic

164
00:07:42,990 --> 00:07:40,270
Atacama Desert or u.s. Southwest and

165
00:07:45,000 --> 00:07:43,000
they tend to be formed by oxidation so

166
00:07:46,830 --> 00:07:45,010
how do we find them unless we actually

167
00:07:50,790 --> 00:07:46,840
send a mission there and so one way

168
00:07:53,220 --> 00:07:50,800
would be through remote sensing and if

169
00:07:55,770 --> 00:07:53,230
you look at the spectral comparison of

170
00:07:58,830 --> 00:07:55,780
different hydrated salts here on the

171
00:08:01,890 --> 00:07:58,840
left you have in green so first I'll say

172
00:08:04,500 --> 00:08:01,900
this is the near-infrared from 1 to 2.5

173
00:08:07,530 --> 00:08:04,510
microns and reflectance on the y axis in

174
00:08:10,770 --> 00:08:07,540
green you have Epsom ight and in purple

175
00:08:13,770 --> 00:08:10,780
you have bischoff it-- so you can see

176
00:08:15,960 --> 00:08:13,780
that the spectral features are actually

177
00:08:18,300 --> 00:08:15,970
very similar to each other and this is

178
00:08:22,260 --> 00:08:18,310
because you're looking at a magnesium

179
00:08:24,510 --> 00:08:22,270
ion wrapped with six or seven waters and

180
00:08:26,610 --> 00:08:24,520
then the anions are actually outside of

181
00:08:28,590 --> 00:08:26,620
it so you're actually really looking at

182
00:08:31,500 --> 00:08:28,600
hydration state that is the dominant

183
00:08:33,990 --> 00:08:31,510
feature in the near infrared spectra of

184
00:08:35,670 --> 00:08:34,000
different hydrated salts and then again

185
00:08:39,030 --> 00:08:35,680
on the right here you can see gypsum

186
00:08:40,230 --> 00:08:39,040
which is a classic spectrum everyone who

187
00:08:44,850 --> 00:08:40,240
sees the spectrum of judgment goes

188
00:08:48,120 --> 00:08:44,860

that's gypsum except magnesium chlorate

189
00:08:51,290 --> 00:08:48,130
to h2o also has this triplet at 1.4

190
00:08:54,900 --> 00:08:51,300
microns and it also has a really weird

191
00:08:57,180 --> 00:08:54,910
1.9 feature there are differences I'm

192
00:08:59,820 --> 00:08:57,190
not saying that one is necessarily being

193
00:09:01,470 --> 00:08:59,830
confused for the other but when we go to

194
00:09:02,879 --> 00:09:01,480
send missions to other planets we need

195
00:09:05,129 --> 00:09:02,889
to be very careful to have

196
00:09:07,139 --> 00:09:05,139
enough resolution and looking at the

197
00:09:10,019 --> 00:09:07,149
context to understand and make sure that

198
00:09:13,889 --> 00:09:10,029
we're seeing the right salts so to that

199
00:09:15,749 --> 00:09:13,899
end I've been relooking at some classic

200
00:09:18,539 --> 00:09:15,759
salty spectra as I mentioned before

201
00:09:20,789 --> 00:09:18,549
there's a Columbus crater here on Mars

202
00:09:24,090 --> 00:09:20,799
again you can see the very nice bathtub

203
00:09:26,789 --> 00:09:24,100
ring and here to zoom and image of it

204
00:09:28,799 --> 00:09:26,799
and if we zoom in even further again

205
00:09:31,949 --> 00:09:28,809
here's that bathtub ring and we can map

206
00:09:35,039 --> 00:09:31,959
the water the hydration feature that 1.9

207
00:09:37,109 --> 00:09:35,049
micron feature and start to pull out

208
00:09:42,509 --> 00:09:37,119
what some of the interesting spectra

209
00:09:46,710 --> 00:09:42,519
might look like thank you so we can see

210
00:09:48,629 --> 00:09:46,720
that there's different there's a lot of

211
00:09:50,699 --> 00:09:48,639
variability even when we just look at

212
00:09:54,539 --> 00:09:50,709
anything that has a hydration band and

213
00:09:56,099 --> 00:09:54,549

so again here this might be one of those

214
00:09:59,220 --> 00:09:56,109
ones that people say aha

215
00:10:01,379 --> 00:09:59,230
it's gypsum so if we zoom in on it

216
00:10:04,530 --> 00:10:01,389
further and we can compare start to

217
00:10:07,319 --> 00:10:04,540
compare it to other salts that have

218
00:10:08,759 --> 00:10:07,329
similar features to it and then what

219
00:10:10,919 --> 00:10:08,769
we're what we're trying to do is

220
00:10:12,900 --> 00:10:10,929
actually create some new parameters that

221
00:10:16,679 --> 00:10:12,910
will help us identify and distinguish

222
00:10:18,199 --> 00:10:16,689
between the different salts so since I

223
00:10:21,509 --> 00:10:18,209
have less than two minutes to go down

224
00:10:23,519 --> 00:10:21,519
I'll quickly move on to the outer solar

225
00:10:27,869 --> 00:10:23,529
system and just say that temperature

226
00:10:32,729 --> 00:10:27,879
also affects the spectra and you can see

227
00:10:35,789 --> 00:10:32,739
here there's three pairs of spectra my

228
00:10:37,650 --> 00:10:35,799
knees and chloride to h2o for h2o and 62

229
00:10:40,289 --> 00:10:37,660
and we have the 80 Kelvin which is

230
00:10:41,999 --> 00:10:40,299
Europa relevant temperature and then the

231
00:10:44,460 --> 00:10:42,009
room temperature one and I'll just maybe

232
00:10:46,590 --> 00:10:44,470
zoom in on this little area here you can

233
00:10:48,569 --> 00:10:46,600
see that at room temperature it's kind

234
00:10:50,879 --> 00:10:48,579
of more of a shoulder whereas at 80

235
00:10:53,369 --> 00:10:50,889
Kelvin it's actually a triplet and more

236
00:10:54,840 --> 00:10:53,379
of a real band and this is again because

237
00:10:58,379 --> 00:10:54,850
as I was saying you have the magnesium

238
00:10:59,639 --> 00:10:58,389

and you have six waters octahedrally

239
00:11:01,439 --> 00:10:59,649
coordinated to it and you're actually

240
00:11:03,269 --> 00:11:01,449
seeing the pairs of vibrations so you're

241
00:11:04,919 --> 00:11:03,279
narrowing the features as you go to

242
00:11:07,499 --> 00:11:04,929
colder temperature and really starting

243
00:11:11,069 --> 00:11:07,509
to resolve the individual features to it

244
00:11:13,439 --> 00:11:11,079
so thinking about Europa there's been a

245
00:11:15,870 --> 00:11:13,449
lot about the non icy component which

246
00:11:21,360 --> 00:11:15,880
would be these red regions on the

247
00:11:23,610 --> 00:11:21,370
right and long story short some

248
00:11:25,290 --> 00:11:23,620
telescopic observations were done using

249
00:11:28,320 --> 00:11:25,300
that laboratory spectra that I just

250
00:11:30,840 --> 00:11:28,330
showed and they found up to on the right

251
00:11:35,340 --> 00:11:30,850
here 35 weight percent of magnesium

252
00:11:39,810 --> 00:11:35,350
chlorine salts in the non icy regions

253
00:11:41,520 --> 00:11:39,820
and about 15 weight percent of magnesium

254
00:11:43,200 --> 00:11:41,530
perchlorate and then you know so the

255
00:11:45,660 --> 00:11:43,210
chlorine and the chloride are actually

256
00:11:47,550 --> 00:11:45,670
not necessarily co-located but typically

257
00:11:51,420 --> 00:11:47,560
in the non icy region

258
00:11:54,000 --> 00:11:51,430
so to summarize thinking about how to

259
00:11:56,280 --> 00:11:54,010
find chlorine salts which of course will

260
00:11:58,740 --> 00:11:56,290
help us elucidate the habitability of

261
00:12:01,020 --> 00:11:58,750
any planet that we're going to spectral

262
00:12:03,990 --> 00:12:01,030
libraries are needed at a range of

263
00:12:07,650 --> 00:12:04,000

hydration States wavelength ranges and

264
00:12:14,010 --> 00:12:07,660
temperatures to be able to actually

265
00:12:16,080 --> 00:12:14,020
identify these salts and yes I said all

266
00:12:20,220 --> 00:12:16,090
that so I'll just go on to the summary

267
00:12:21,780 --> 00:12:20,230
which is that the chlorine Sol's do tend

268
00:12:24,390 --> 00:12:21,790
to be globally distributed Mars we've

269
00:12:25,920 --> 00:12:24,400
seen them across different ranges and we

270
00:12:28,290 --> 00:12:25,930
do think that we can actually start to

271
00:12:29,310 --> 00:12:28,300
identify them with our new special

272
00:12:32,940 --> 00:12:29,320
parameters

273
00:12:35,220 --> 00:12:32,950
Europa's non icy non sulfuric acid

274
00:12:37,050 --> 00:12:35,230
component likely includes chlorine salts

275
00:12:39,690 --> 00:12:37,060
and it's important to differentiate

276
00:12:41,850 --> 00:12:39,700
between between the chlorides and

277
00:12:44,580 --> 00:12:41,860
perchlorates between chlorine salts and

278
00:12:46,680 --> 00:12:44,590
sulfates because all these salts have

279
00:12:49,650 --> 00:12:46,690
vastly different effects on the

280
00:12:53,100 --> 00:12:49,660
habitability and stability of the liquid

281
00:12:57,170 --> 00:12:53,110
water thank you

282
00:13:00,570 --> 00:12:57,180
[Applause]

283
00:13:08,270 --> 00:13:00,580
time for questions for Jen if anyone

284
00:13:11,960 --> 00:13:08,280
wants to come up does anyone dare it's

285
00:13:21,120 --> 00:13:16,700
Marty low risk it I think I can it stand

286
00:13:23,670 --> 00:13:21,130
hi Jen a multi-party JPL wonderful talk

287
00:13:27,090 --> 00:13:23,680
and also the video that you showed in

288
00:13:31,750 --> 00:13:27,100

the vetting or

289
00:13:33,790 --> 00:13:31,760
other questions yeah do you think that

290
00:13:36,070 --> 00:13:33,800
the grain size will also play an

291
00:13:38,200 --> 00:13:36,080
important role in respecting property

292
00:13:40,930 --> 00:13:38,210
absolutely I did not mention it I should

293
00:13:43,470 --> 00:13:40,940
have absolutely if so I want to pitch in

294
00:13:47,079 --> 00:13:43,480
here that we there's an excellent

295
00:13:49,600 --> 00:13:47,089
graduate student from Alyssia who is who

296
00:13:51,820 --> 00:13:49,610
has built two instrument in our lab we

297
00:13:55,300 --> 00:13:51,830
are trying to do grain size dependent

298
00:14:03,790 --> 00:13:55,310
spectroscopy under irradiation for any

299
00:14:05,440 --> 00:14:03,800
kind of icy material great hi I'm

300
00:14:07,720 --> 00:14:05,450
Marshall satinsky from University of

301
00:14:09,070 --> 00:14:07,730
Washington and I just wanted to thank

302
00:14:10,480 --> 00:14:09,080
you for going into the detail about the

303
00:14:13,090 --> 00:14:10,490
salts at the start because part of the

304
00:14:14,980 --> 00:14:13,100
joy of apps icon is I'm not an expert in

305
00:14:16,060 --> 00:14:14,990
salts and this is session that I wanted

306
00:14:18,519 --> 00:14:16,070
to go to because it's something that I

307
00:14:19,930 --> 00:14:18,529
want to shore up some of that gaps in my

308
00:14:21,340 --> 00:14:19,940
understanding so those sorts of things

309
00:14:24,540 --> 00:14:21,350
are very helpful for me and I'm sure not

310
00:14:27,400 --> 00:14:24,550
the only one my pleasure thank you and

311
00:14:28,560 --> 00:14:27,410
with that let's give her a round of