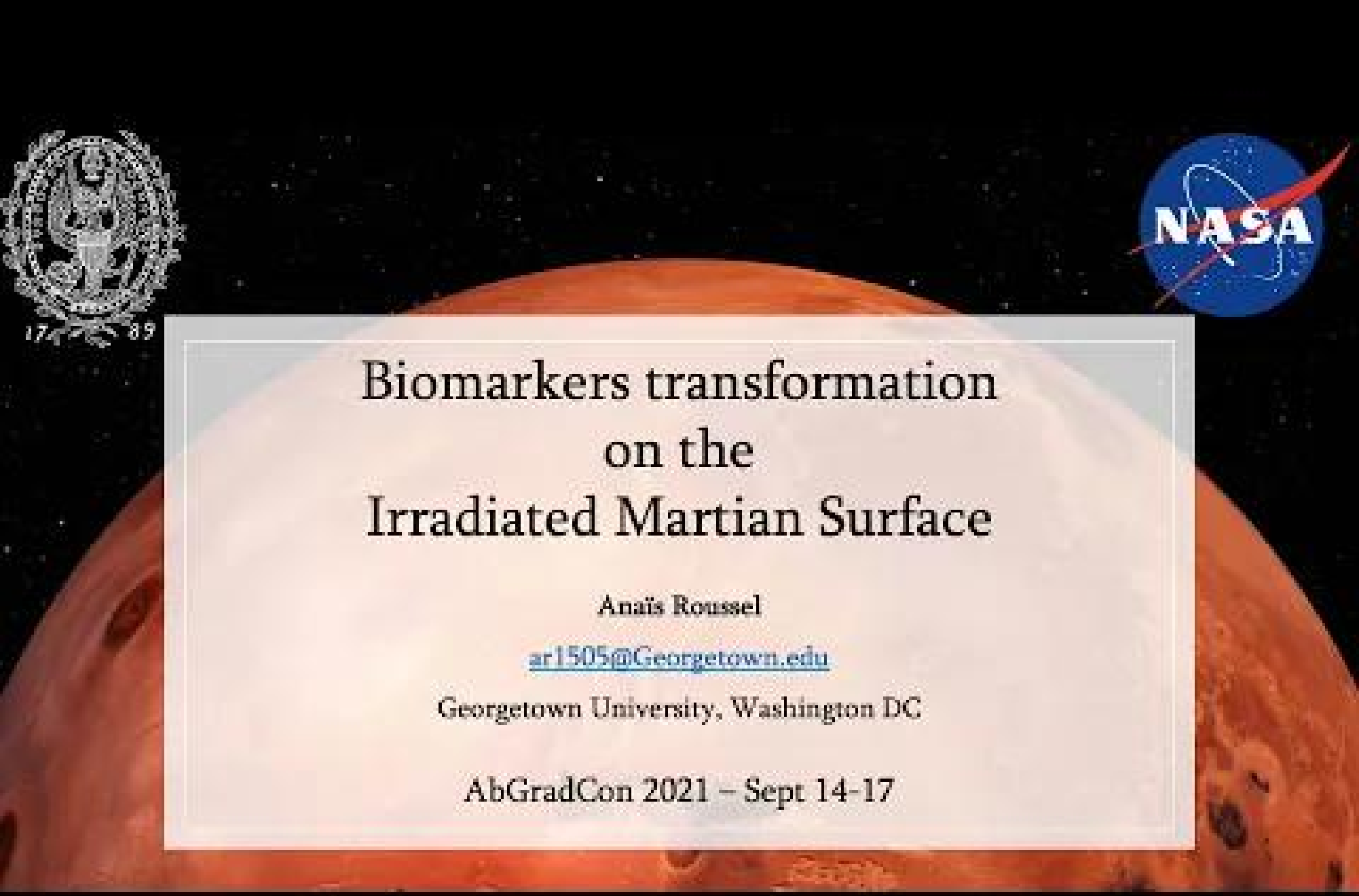

Biomarkers transformation on the Irradiated Martian Surface

Anaïs Roussel

ar1505@Georgetown.edu

Georgetown University, Washington DC

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1
00:00:09,589 --> 00:00:07,030
thanks to decades of research and

2
00:00:11,350 --> 00:00:09,599
several missions like curiosity here

3
00:00:13,190 --> 00:00:11,360
we know today that mars used to be

4
00:00:14,390 --> 00:00:13,200
habitable in the beginning of its

5
00:00:16,470 --> 00:00:14,400
history

6
00:00:18,710 --> 00:00:16,480
it had a dense atmosphere

7
00:00:21,109 --> 00:00:18,720
a global northern ocean

8
00:00:22,710 --> 00:00:21,119
rivers and lakes and temperatures

9
00:00:25,990 --> 00:00:22,720
similar to earth

10
00:00:28,230 --> 00:00:26,000
but unfortunately four billion years ago

11
00:00:30,550 --> 00:00:28,240
it lost its magnetic field

12
00:00:32,790 --> 00:00:30,560
and without this protection the planet

13
00:00:35,590 --> 00:00:32,800

progressively turned into the freezing

14
00:00:38,069 --> 00:00:35,600
irradiated desert we know today

15
00:00:41,190 --> 00:00:38,079
however there is a small window of

16
00:00:43,830 --> 00:00:41,200
habitability and the big question is

17
00:00:46,709 --> 00:00:43,840
did life appear before the planet lost

18
00:00:50,470 --> 00:00:46,719
its magnetic field and did it leave any

19
00:00:52,470 --> 00:00:50,480
trace we can detect today

20
00:00:54,630 --> 00:00:52,480
to answer these questions we're sending

21
00:00:56,950 --> 00:00:54,640
rovers to the red planet

22
00:00:59,029 --> 00:00:56,960
and both perseverance and the rosalind

23
00:01:01,510 --> 00:00:59,039
franklin rovers have four main

24
00:01:02,470 --> 00:01:01,520
objectives to detect traces of ancient

25
00:01:04,710 --> 00:01:02,480
life

26
00:01:06,469 --> 00:01:04,720
later in the presentation i'll present

27
00:01:08,310 --> 00:01:06,479
you one type of these by signatures

28
00:01:10,550 --> 00:01:08,320
we're looking for

29
00:01:13,510 --> 00:01:10,560
but here you can quickly see how

30
00:01:16,310 --> 00:01:13,520
important their detection is so in order

31
00:01:18,230 --> 00:01:16,320
to know what instruments to use on mars

32
00:01:20,789 --> 00:01:18,240
where to send them to have a maximum

33
00:01:23,190 --> 00:01:20,799
chance to find potential signatures we

34
00:01:26,390 --> 00:01:23,200
need to understand how these clues can

35
00:01:28,550 --> 00:01:26,400
be degraded over time

36
00:01:31,830 --> 00:01:28,560
to understand how biosignature degrade

37
00:01:33,749 --> 00:01:31,840
on mars we use earth as an analog

38
00:01:35,990 --> 00:01:33,759

here is an example of all the steps that

39
00:01:38,550 --> 00:01:36,000
could degrade these signatures between

40
00:01:41,910 --> 00:01:38,560
the organisms living in a paleo basin

41
00:01:43,910 --> 00:01:41,920
and now first the incorporation into the

42
00:01:44,870 --> 00:01:43,920
sediments without being degraded or

43
00:01:46,389 --> 00:01:44,880
eaten

44
00:01:48,230 --> 00:01:46,399
then the higher pressures and

45
00:01:49,749 --> 00:01:48,240
temperatures experienced during

46
00:01:51,670 --> 00:01:49,759
diogenesis

47
00:01:53,910 --> 00:01:51,680
followed by additional potential

48
00:01:56,389 --> 00:01:53,920
exposures to water oxygen or

49
00:01:58,310 --> 00:01:56,399
microorganisms via fractures

50
00:02:01,030 --> 00:01:58,320
and for the scientists to be able to

51
00:02:03,270 --> 00:02:01,040
collect and study these samples we need

52
00:02:05,670 --> 00:02:03,280
them to be closer to the surface which

53
00:02:09,109 --> 00:02:05,680
once again brings a lot of possible ways

54
00:02:11,910 --> 00:02:09,119
to erase our traces of ancient life

55
00:02:15,430 --> 00:02:11,920
but that is for earth and mars has an

56
00:02:17,990 --> 00:02:15,440
additional powerful destructive agent

57
00:02:20,790 --> 00:02:18,000
indeed because it's lost its magnetic

58
00:02:22,390 --> 00:02:20,800
field the martian surface is exposed to

59
00:02:24,949 --> 00:02:22,400
heavy radiation

60
00:02:27,430 --> 00:02:24,959
the first type and most abundant are the

61
00:02:28,949 --> 00:02:27,440
solar energetic particles they are

62
00:02:31,190 --> 00:02:28,959
absorbed in the very first two

63
00:02:34,550 --> 00:02:31,200

centimeters of the surface

64
00:02:36,710 --> 00:02:34,560
the second type are galactic cosmic rays

65
00:02:39,270 --> 00:02:36,720
they are less frequent but much more

66
00:02:40,229 --> 00:02:39,280
powerful and penetrate deeper under the

67
00:02:42,470 --> 00:02:40,239
surface

68
00:02:43,910 --> 00:02:42,480
up to several meters down according to

69
00:02:46,150 --> 00:02:43,920
models

70
00:02:48,550 --> 00:02:46,160
there they will react with the soil and

71
00:02:51,190 --> 00:02:48,560
produce showers of secondary radiation

72
00:02:53,110 --> 00:02:51,200
including gamma radiation

73
00:02:55,030 --> 00:02:53,120
when we look at the depth where these

74
00:02:57,190 --> 00:02:55,040
rovers are drilling we see that the

75
00:02:59,430 --> 00:02:57,200
cosmic rays could have an impact on the

76
00:03:02,149 --> 00:02:59,440
about signatures we're looking for

77
00:03:05,110 --> 00:03:02,159
so the main question becomes are any

78
00:03:07,110 --> 00:03:05,120
biosignature left at this depth and

79
00:03:09,190 --> 00:03:07,120
knowing that would help us determine

80
00:03:12,070 --> 00:03:09,200
where to send the rovers and what to

81
00:03:16,550 --> 00:03:14,470
to take in account this radiation

82
00:03:18,869 --> 00:03:16,560
part of my project is to irradiate

83
00:03:20,869 --> 00:03:18,879
different types of analog terrestrial

84
00:03:22,309 --> 00:03:20,879
samples that naturally preserved

85
00:03:24,710 --> 00:03:22,319
biomarkers

86
00:03:27,190 --> 00:03:24,720
i'm focusing on cosmic rays because as

87
00:03:29,589 --> 00:03:27,200
we just saw they're the main ones at the

88
00:03:32,390 --> 00:03:29,599

depth where the rovers are drilling and

89
00:03:34,470 --> 00:03:32,400
i use gamma rays as analog because it's

90
00:03:37,430 --> 00:03:34,480
one of the main degradation products

91
00:03:40,070 --> 00:03:37,440
when the cosmic rays hit the surface

92
00:03:43,910 --> 00:03:40,080
for today's presentation i will focus on

93
00:03:46,869 --> 00:03:43,920
shells samples shells are fossilized mud

94
00:03:49,030 --> 00:03:46,879
we have the n shell here on the left

95
00:03:50,869 --> 00:03:49,040
with the physical trace of a leaf and

96
00:03:52,070 --> 00:03:50,879
the muscle shell on the right with the

97
00:03:54,949 --> 00:03:52,080
fish

98
00:03:57,110 --> 00:03:54,959
and amongst a variety of biosignature

99
00:03:59,030 --> 00:03:57,120
they're both containing typical lipid

100
00:04:01,910 --> 00:03:59,040
fossils that i will present in a few

101
00:04:03,990 --> 00:04:01,920
slides not only fossils from the fish

102
00:04:06,390 --> 00:04:04,000
and the leaves that you can see but also

103
00:04:10,470 --> 00:04:06,400
from microbial sources that are not

104
00:04:15,670 --> 00:04:12,869
after a lot of sample preparation here

105
00:04:18,390 --> 00:04:15,680
are they ready to be irradiated

106
00:04:20,550 --> 00:04:18,400
they have been packed flame sealed under

107
00:04:23,030 --> 00:04:20,560
vacuum and the bottom of the tube is

108
00:04:24,870 --> 00:04:23,040
facing the radiation source

109
00:04:26,790 --> 00:04:24,880
and this is how they looked like after

110
00:04:28,790 --> 00:04:26,800
radiation

111
00:04:30,870 --> 00:04:28,800
they were exposed to a dose equivalent

112
00:04:33,110 --> 00:04:30,880
to 15 million years on the martian

113
00:04:34,870 --> 00:04:33,120

surface with gamma rays

114
00:04:37,110 --> 00:04:34,880
and then we compared the molecular

115
00:04:38,950 --> 00:04:37,120
fossils content and quantities between

116
00:04:42,230 --> 00:04:38,960
the controls that haven't been

117
00:04:43,670 --> 00:04:42,240
irradiated and irradiated samples if we

118
00:04:45,590 --> 00:04:43,680
don't see any difference it's a good

119
00:04:47,510 --> 00:04:45,600
sign for the rovers and we can keep

120
00:04:49,909 --> 00:04:47,520
increasing the dose to higher levels of

121
00:04:51,189 --> 00:04:49,919
radiation to see where the trend is

122
00:04:52,790 --> 00:04:51,199
going

123
00:04:55,350 --> 00:04:52,800
and if we observe a decrease in

124
00:04:57,670 --> 00:04:55,360
biomarkers content our objective was to

125
00:05:00,870 --> 00:04:57,680
characterize the rate and compare it in

126
00:05:02,950 --> 00:05:00,880
different types of samples

127
00:05:05,110 --> 00:05:02,960
i'm going to focus for this presentation

128
00:05:07,670 --> 00:05:05,120
on a specific type of biosignatures

129
00:05:09,990 --> 00:05:07,680
belonging to lipid biomarkers

130
00:05:11,990 --> 00:05:10,000
the first types are hopets there are

131
00:05:14,469 --> 00:05:12,000
fossils of hopanoles which are membrane

132
00:05:16,550 --> 00:05:14,479
lipids found in prokaryotes as you can

133
00:05:18,230 --> 00:05:16,560
see during diagenesis we are losing

134
00:05:20,950 --> 00:05:18,240
functional groups but we keep the

135
00:05:23,189 --> 00:05:20,960
diagnostic hydrocarbon skeleton

136
00:05:25,029 --> 00:05:23,199
and this structure if found on another

137
00:05:26,870 --> 00:05:25,039
planet is complex enough to be

138
00:05:28,710 --> 00:05:26,880

diagnostic of life

139
00:05:30,710 --> 00:05:28,720
we don't know any way to synthesize this

140
00:05:33,990 --> 00:05:30,720
abiotically

141
00:05:35,909 --> 00:05:34,000
the second biomarker are alkanes

142
00:05:38,870 --> 00:05:35,919
they can be degraded from fatty acids

143
00:05:40,870 --> 00:05:38,880
here as we can see in this case a simple

144
00:05:43,990 --> 00:05:40,880
chain of carbon can be formed without

145
00:05:45,990 --> 00:05:44,000
life so it's not that one molecule alone

146
00:05:48,390 --> 00:05:46,000
that will give us any information about

147
00:05:50,550 --> 00:05:48,400
past life but the distribution of

148
00:05:52,950 --> 00:05:50,560
alkanes in a sample

149
00:05:56,550 --> 00:05:52,960
if they're mostly long chains or short

150
00:05:59,749 --> 00:05:56,560
chains or if they have a higher amount

151
00:06:01,909 --> 00:05:59,759
of even or odd carbon number etc

152
00:06:03,990 --> 00:06:01,919
and the rovers that we sent on mars have

153
00:06:06,710 --> 00:06:04,000
the ability to detect these hydrocarbons

154
00:06:11,270 --> 00:06:06,720
and to answer our questions but we

155
00:06:15,909 --> 00:06:13,430
first we compared the total organic

156
00:06:18,469 --> 00:06:15,919
carbon in our samples and spell on the

157
00:06:20,309 --> 00:06:18,479
left muscle on the right the controls

158
00:06:21,909 --> 00:06:20,319
here are in blue and the irradiated

159
00:06:24,150 --> 00:06:21,919
sample in orange

160
00:06:26,469 --> 00:06:24,160
the arrow bar here represents the

161
00:06:28,309 --> 00:06:26,479
natural variation of the sample so we

162
00:06:29,270 --> 00:06:28,319
see that there is no significant change

163
00:06:31,830 --> 00:06:29,280

here

164
00:06:33,670 --> 00:06:31,840
so far it's a good sign for the rovers

165
00:06:36,150 --> 00:06:33,680
but here is what we saw for the

166
00:06:37,830 --> 00:06:36,160
hydrocarbons

167
00:06:40,230 --> 00:06:37,840
they increased

168
00:06:42,070 --> 00:06:40,240
here is only semi-quantitative data this

169
00:06:44,710 --> 00:06:42,080
is why we don't have any error bars for

170
00:06:46,629 --> 00:06:44,720
natural variation but at these levels we

171
00:06:49,270 --> 00:06:46,639
can be confident that the amount of

172
00:06:51,990 --> 00:06:49,280
hydrocarbon is almost doubling after

173
00:06:56,309 --> 00:06:52,000
radiation so we decided to look more

174
00:06:59,270 --> 00:06:56,319
specifically in our targeted biomarkers

175
00:07:01,670 --> 00:06:59,280
first we looked at the linear alkanes

176
00:07:03,430 --> 00:07:01,680
and same thing they increased to even

177
00:07:05,589 --> 00:07:03,440
higher proportions

178
00:07:07,430 --> 00:07:05,599
after seeing that we were curious in

179
00:07:09,990 --> 00:07:07,440
their distribution because as i

180
00:07:12,070 --> 00:07:10,000
mentioned before the distribution is the

181
00:07:14,550 --> 00:07:12,080
actual signature here

182
00:07:16,950 --> 00:07:14,560
here are the results with the size of

183
00:07:19,350 --> 00:07:16,960
the carbon chain on the x-axis

184
00:07:21,670 --> 00:07:19,360
and we can see that for both samples

185
00:07:24,390 --> 00:07:21,680
even if the quantities after radiation

186
00:07:26,950 --> 00:07:24,400
are larger the distribution itself

187
00:07:30,070 --> 00:07:26,960
doesn't seem to change much we don't

188
00:07:32,390 --> 00:07:30,080

suddenly have only large or only short

189
00:07:35,350 --> 00:07:32,400
carbon chains for examples

190
00:07:39,990 --> 00:07:35,360
so for alkanes the signal is not only

191
00:07:43,029 --> 00:07:40,000
preserved but increased after radiation

192
00:07:45,830 --> 00:07:43,039
for hopping's biosignature it is not as

193
00:07:48,390 --> 00:07:45,840
clear as it was for alkanes same thing

194
00:07:50,710 --> 00:07:48,400
again our two samples before and after

195
00:07:52,869 --> 00:07:50,720
radiation and some of the whole pains we

196
00:07:55,510 --> 00:07:52,879
identified in the samples

197
00:07:58,150 --> 00:07:55,520
again this is not precise quantification

198
00:08:00,629 --> 00:07:58,160
so it's hard to make strong conclusions

199
00:08:04,629 --> 00:08:00,639
but we see different trains

200
00:08:07,189 --> 00:08:04,639
some stay at the same similar abundances

201
00:08:09,110 --> 00:08:07,199
here in n-spell this one is decreasing

202
00:08:11,830 --> 00:08:09,120
by almost half

203
00:08:14,150 --> 00:08:11,840
and here these last two muscles are

204
00:08:16,309 --> 00:08:14,160
doubling we don't expect radiation to

205
00:08:18,390 --> 00:08:16,319
lead to the synthesis of any of these

206
00:08:20,950 --> 00:08:18,400
because they're very complex but we have

207
00:08:23,670 --> 00:08:20,960
a few hypotheses for whole pains and

208
00:08:25,749 --> 00:08:23,680
overall for a hydrocarbon increase after

209
00:08:27,909 --> 00:08:25,759
radiation

210
00:08:29,990 --> 00:08:27,919
concerning hope pains most of the

211
00:08:31,110 --> 00:08:30,000
variation we see could be natural

212
00:08:32,949 --> 00:08:31,120
variation

213
00:08:35,190 --> 00:08:32,959

for this we will do additional

214
00:08:37,589 --> 00:08:35,200
quantitative analysis

215
00:08:39,509 --> 00:08:37,599
but there are a lot of other molecules

216
00:08:41,509 --> 00:08:39,519
in the samples that we don't see in our

217
00:08:43,350 --> 00:08:41,519
runs due to the methods and the

218
00:08:44,949 --> 00:08:43,360
instrument we used

219
00:08:47,509 --> 00:08:44,959
one of them are refractory

220
00:08:49,190 --> 00:08:47,519
macromolecules like kerogen or

221
00:08:51,350 --> 00:08:49,200
asphaltenes

222
00:08:53,590 --> 00:08:51,360
here is an example of their very complex

223
00:08:56,710 --> 00:08:53,600
macro structure making them not

224
00:08:58,230 --> 00:08:56,720
extractable by our method or visible by

225
00:09:00,550 --> 00:08:58,240
our instruments

226
00:09:03,910 --> 00:09:00,560
but under radiation they could break

227
00:09:06,389 --> 00:09:03,920
down and liberate alkanes propanes or a

228
00:09:08,630 --> 00:09:06,399
variety of other hydrocarbons

229
00:09:10,949 --> 00:09:08,640
and even if they don't fully break down

230
00:09:13,829 --> 00:09:10,959
radiation could liberate pockets of

231
00:09:16,070 --> 00:09:13,839
adsorbed or occluded hydrocarbons that

232
00:09:18,389 --> 00:09:16,080
we now can detect

233
00:09:20,550 --> 00:09:18,399
for this hypothesis we will irradiate

234
00:09:22,470 --> 00:09:20,560
standards of kerogen and see if anything

235
00:09:25,269 --> 00:09:22,480
is liberated

236
00:09:27,910 --> 00:09:25,279
our last hypothesis is that our very

237
00:09:30,389 --> 00:09:27,920
well-preserved sample still contain

238
00:09:32,870 --> 00:09:30,399

fresher organics like fatty acids that

239
00:09:35,509 --> 00:09:32,880
wouldn't be detected in the hydrocarbon

240
00:09:37,990 --> 00:09:35,519
phase because they are still polar

241
00:09:40,630 --> 00:09:38,000
but they could be degraded into alkanes

242
00:09:42,630 --> 00:09:40,640
during exposure to gamma rays we will

243
00:09:46,870 --> 00:09:42,640
hear irradiate standards of fatty acid

244
00:09:48,829 --> 00:09:46,880
to see if any hydrocarbon is created

245
00:09:52,070 --> 00:09:48,839
here is another way to represent our

246
00:09:54,070 --> 00:09:52,080
hypothesis the total organic carbon here

247
00:09:55,509 --> 00:09:54,080
in the blue box doesn't change after

248
00:09:58,550 --> 00:09:55,519
radiation

249
00:10:01,269 --> 00:09:58,560
then a part of that organic carbon are

250
00:10:04,069 --> 00:10:01,279
the extractable hydrocarbon that we see

251
00:10:05,829 --> 00:10:04,079
in our rounds they double in size as you

252
00:10:07,910 --> 00:10:05,839
can see the green box

253
00:10:09,910 --> 00:10:07,920
they include the alkanes that were

254
00:10:12,150 --> 00:10:09,920
increased by a factor of two to almost

255
00:10:13,670 --> 00:10:12,160
four and the whole panes for which we

256
00:10:15,350 --> 00:10:13,680
need more

257
00:10:17,110 --> 00:10:15,360
analysis to be conclusive about

258
00:10:18,550 --> 00:10:17,120
quantification

259
00:10:20,630 --> 00:10:18,560
outside the box

260
00:10:23,190 --> 00:10:20,640
of extractable hydrocarbons we have the

261
00:10:24,949 --> 00:10:23,200
macromolecules in gray

262
00:10:27,829 --> 00:10:24,959
that could freeze some hydrocarbons

263
00:10:29,990 --> 00:10:27,839

under radiation or fatty acids in dark

264
00:10:32,470 --> 00:10:30,000
blue that could be degraded also into

265
00:10:36,230 --> 00:10:32,480
hydrocarbons or it could also be a

266
00:10:38,150 --> 00:10:36,240
complex mix of all these processes

267
00:10:40,870 --> 00:10:38,160
these counter-intuitive but very

268
00:10:43,030 --> 00:10:40,880
exciting results opened a whole new plan

269
00:10:46,150 --> 00:10:43,040
of work to understand what is happening

270
00:10:48,389 --> 00:10:46,160
to our biomarkers and the radiation

271
00:10:50,389 --> 00:10:48,399
first we will analyze our samples with

272
00:10:52,470 --> 00:10:50,399
precise quantitative instruments to

273
00:10:54,630 --> 00:10:52,480
determine real trends

274
00:10:57,269 --> 00:10:54,640
then we will re-irradiate the same

275
00:10:59,590 --> 00:10:57,279
samples but at higher doses to see how

276
00:11:02,310 --> 00:10:59,600
the trend is evolving the results you

277
00:11:05,350 --> 00:11:02,320
saw were for 15 million years and as a

278
00:11:07,750 --> 00:11:05,360
comparison gel crater where curiosity is

279
00:11:09,670 --> 00:11:07,760
right now has been irradiated for about

280
00:11:12,069 --> 00:11:09,680
80 million years

281
00:11:14,389 --> 00:11:12,079
as we mentioned before we will also

282
00:11:16,710 --> 00:11:14,399
irradiate macromolecules and fatty acid

283
00:11:19,190 --> 00:11:16,720
standards to figure out if they can

284
00:11:21,350 --> 00:11:19,200
produce hydrocarbons

285
00:11:23,670 --> 00:11:21,360
and lastly in this presentation we

286
00:11:26,389 --> 00:11:23,680
focused on quantifying biomarkers that

287
00:11:28,310 --> 00:11:26,399
were present in the controls but another

288
00:11:30,389 --> 00:11:28,320

question would be to know if radiation

289
00:11:32,389 --> 00:11:30,399
could be creating new types of

290
00:11:36,069 --> 00:11:32,399
biomarkers that we could look for

291
00:11:40,949 --> 00:11:38,230
with this i'd like to thank georgetown

292
00:11:43,269 --> 00:11:40,959
university to johnson's lab and the

293
00:11:45,990 --> 00:11:43,279
radiation facility at nasa goddard for

294
00:11:47,990 --> 00:11:46,000
irradiating our samples

295
00:11:49,350 --> 00:11:48,000
thank you very much for your attention