1
00:00:10,470 --> 00:00:08,710
i am the chair for the session this

2
00:00:12,709 --> 00:00:10,480
morning my name is brett mcguire my name

3
00:00:15,430 --> 00:00:12,719
is on the slide i'm giving a warm-up

4
00:00:17,670 --> 00:00:15,440
talk here i also have the privilege uh

5
00:00:19,910 --> 00:00:17,680
since we didn't plan ahead to uh

6
00:00:20,950 --> 00:00:19,920
welcome you all to the uh the conference

7
00:00:23,830 --> 00:00:20,960
the 10th

8
00:00:25,670 --> 00:00:23,840
annual astrobiology graduate conference

9
00:00:26,710 --> 00:00:25,680
uh it's a really fantastic opportunity

10
00:00:29,029 --> 00:00:26,720
we're going to get to hear a lot of

11
00:00:32,389 --> 00:00:29,039
talks crammed into two days and then

12
00:00:33,350 --> 00:00:32,399
fame lab or the field trip tomorrow be a

13
00:00:35,190 --> 00:00:33,360

blast

14
00:00:36,870 --> 00:00:35,200
uh

15
00:00:39,430 --> 00:00:36,880
one of the reasons we have these warm-up

16
00:00:41,590 --> 00:00:39,440
talks historically is because this is a

17
00:00:43,430 --> 00:00:41,600
really really broad audience right and

18
00:00:45,110 --> 00:00:43,440
so if you hear me joking around here i'm

19
00:00:46,709 --> 00:00:45,120
giving a warm-up talk on a subject i'm

20
00:00:49,830 --> 00:00:46,719
not even familiar with

21
00:00:52,470 --> 00:00:49,840
uh half of the talk so the purpose of

22
00:00:54,310 --> 00:00:52,480
these and they'll be one either in the

23
00:00:56,069 --> 00:00:54,320
morning or the afternoon and one of them

24
00:00:57,990 --> 00:00:56,079
is split up even between two sessions

25
00:01:00,709 --> 00:00:58,000
because they're so diverse is just to

26
00:01:01,990 --> 00:01:00,719
give you a flavor of the kinds of things

27
00:01:03,029 --> 00:01:02,000
you're going to be talked about in that

28
00:01:05,990 --> 00:01:03,039
session

29
00:01:07,270 --> 00:01:06,000
so for for this one solar system bodies

30
00:01:09,510 --> 00:01:07,280
here it's the second session this

31
00:01:10,710 --> 00:01:09,520
morning i don't know anything about this

32
00:01:12,230 --> 00:01:10,720
so what i did is i just went to

33
00:01:14,710 --> 00:01:12,240
wikipedia and found all the things that

34
00:01:16,230 --> 00:01:14,720
i found cool about mars and europa and

35
00:01:17,670 --> 00:01:16,240
said oh maybe people would be interested

36
00:01:19,270 --> 00:01:17,680
in that

37
00:01:20,390 --> 00:01:19,280
so that's what we're going to do i don't

38
00:01:22,070 --> 00:01:20,400

know what the other warm-up talks are

39
00:01:24,230 --> 00:01:22,080
going to be like but that's the general

40
00:01:26,230 --> 00:01:24,240
idea to give you a flavor but

41
00:01:28,070 --> 00:01:26,240
this is also the warm-up talk for the

42
00:01:30,870 --> 00:01:28,080
entire conference so i thought i'd give

43
00:01:32,550 --> 00:01:30,880
you just a brief preview of uh what the

44
00:01:34,710 --> 00:01:32,560
people that organized this conference

45
00:01:36,310 --> 00:01:34,720
are like uh so you get an idea of how

46
00:01:38,069 --> 00:01:36,320
this is run so as you can imagine we've

47
00:01:39,590 --> 00:01:38,079
sent a lot of emails back and forth over

48
00:01:43,510 --> 00:01:39,600
the last few months

49
00:01:46,310 --> 00:01:43,520
and they have degraded in uh uh

50
00:01:49,910 --> 00:01:46,320
quality and uh robust uh

51
00:01:52,789 --> 00:01:49,920
obeseness i guess so here's a sample of

52
00:01:54,789 --> 00:01:52,799
the one-line subjects one-word subjects

53
00:01:56,310 --> 00:01:54,799
that have been sent as just in the last

54
00:01:58,389 --> 00:01:56,320
two months

55
00:01:59,510 --> 00:01:58,399
which is pretty fantastic and we also

56
00:02:02,630 --> 00:01:59,520
recently

57
00:02:05,749 --> 00:02:02,640
uh devolved into expressing our feelings

58
00:02:09,270 --> 00:02:08,070
and this is just a small selection of

59
00:02:11,510 --> 00:02:09,280
those

60
00:02:13,510 --> 00:02:11,520
we also have been all assigned

61
00:02:15,190 --> 00:02:13,520
characters from firefly which fit our

62
00:02:16,869 --> 00:02:15,200
personalities and roles in this

63
00:02:18,630 --> 00:02:16,879

conference apparently

64
00:02:19,910 --> 00:02:18,640
uh and just one last thing to introduce

65
00:02:23,589 --> 00:02:19,920
you he'll be talking a little bit later

66
00:02:25,750 --> 00:02:23,599
to our fearless leader bradley berker

67
00:02:28,790 --> 00:02:25,760
here he is at rfg on the balcony that he

68
00:02:32,710 --> 00:02:30,630
so if you have questions go ask him as

69
00:02:36,309 --> 00:02:32,720
long as you can find him

70
00:02:40,309 --> 00:02:37,670
there aren't any balconies around here

71
00:02:44,309 --> 00:02:42,070
fantastic

72
00:02:46,470 --> 00:02:44,319
all right so let's see warm-up talk

73
00:02:47,990 --> 00:02:46,480
since we started a little bit late uh

74
00:02:49,830 --> 00:02:48,000
and feel free to interrupt me at any

75
00:02:52,550 --> 00:02:49,840
time if you have questions i don't

76
00:02:54,550 --> 00:02:52,560
doesn't bother me whatsoever uh so the

77
00:02:56,070 --> 00:02:54,560
first half of this is

78
00:02:57,350 --> 00:02:56,080
uh oh

79
00:02:58,229 --> 00:02:57,360
i will do this

80
00:03:01,110 --> 00:02:58,239
uh

81
00:03:01,990 --> 00:03:01,120
never mind i wrote this at rfg yesterday

82
00:03:03,670 --> 00:03:02,000
so

83
00:03:05,430 --> 00:03:03,680
uh

84
00:03:07,670 --> 00:03:05,440
at cal i'm i'm a caltech graduate

85
00:03:10,790 --> 00:03:07,680
student and at caltech we just started a

86
00:03:13,670 --> 00:03:10,800
summer seminar series with uh professors

87
00:03:15,270 --> 00:03:13,680
giving talks on their science which is

88
00:03:16,229 --> 00:03:15,280

something doesn't happen very often

89
00:03:18,390 --> 00:03:16,239
actually you don't get to hear your

90
00:03:19,750 --> 00:03:18,400
professors give talks and we've had two

91
00:03:22,229 --> 00:03:19,760
so far and they've been really great and

92
00:03:23,509 --> 00:03:22,239
they both brought up this idea of great

93
00:03:24,790 --> 00:03:23,519
questions

94
00:03:27,910 --> 00:03:24,800
in science that they think are going to

95
00:03:29,750 --> 00:03:27,920
be solved over the next 30 to 50 years

96
00:03:31,190 --> 00:03:29,760
these are the big things that have to be

97
00:03:33,990 --> 00:03:31,200
addressed and one of them a guy named

98
00:03:36,949 --> 00:03:34,000
harry gray he's a he's a riot he talks

99
00:03:41,270 --> 00:03:36,959
about uh splitting water here does this

100
00:03:44,229 --> 00:03:42,229
all right

101
00:03:45,910 --> 00:03:44,239
splitting water to make energy from

102
00:03:47,670 --> 00:03:45,920
solar light all right this is the next

103
00:03:50,070 --> 00:03:47,680
great advancement in human civilization

104
00:03:51,270 --> 00:03:50,080
and energy according to harry gray

105
00:03:53,509 --> 00:03:51,280
because without this we're just going to

106
00:03:55,509 --> 00:03:53,519
run out of fuel to power our lives and

107
00:03:58,309 --> 00:03:55,519
and that's not very good for us

108
00:04:00,229 --> 00:03:58,319
hey that's much better all right

109
00:04:02,949 --> 00:04:00,239
and we had another talk a guy named

110
00:04:05,190 --> 00:04:02,959
dennis dougherty and he said

111
00:04:05,910 --> 00:04:05,200
other great question is the human mind

112
00:04:09,350 --> 00:04:05,920
so

113
00:04:12,149 --> 00:04:09,360

understanding how we work right from a

114
00:04:13,990 --> 00:04:12,159
molecular level so he works on

115
00:04:16,069 --> 00:04:14,000
signaling pathways in the brain and

116
00:04:17,990 --> 00:04:16,079
understanding neurotransmitters right

117
00:04:19,830 --> 00:04:18,000
and he says this is the most complex

118
00:04:21,430 --> 00:04:19,840
piece of machinery on the planet it's a

119
00:04:24,070 --> 00:04:21,440
human brain

120
00:04:25,909 --> 00:04:24,080
so two great questions are how do we

121
00:04:27,350 --> 00:04:25,919
work and how are we going to continue to

122
00:04:29,030 --> 00:04:27,360
survive and

123
00:04:30,790 --> 00:04:29,040
i think this may be presumptuous from a

124
00:04:32,710 --> 00:04:30,800
graduate student but a third great

125
00:04:36,150 --> 00:04:32,720
question is when are we going to find

126
00:04:38,870 --> 00:04:36,160
alien life are we alone in the universe

127
00:04:40,310 --> 00:04:38,880
right and and this has

128
00:04:42,629 --> 00:04:40,320
general implications for the conference

129
00:04:45,270 --> 00:04:42,639
right this is astrobiology

130
00:04:47,110 --> 00:04:45,280
uh but it encompasses a whole range of

131
00:04:49,590 --> 00:04:47,120
topics and we're going to talk about all

132
00:04:51,510 --> 00:04:49,600
of them today right it's not so specific

133
00:04:53,670 --> 00:04:51,520
say splitting water but

134
00:04:55,270 --> 00:04:53,680
how did life arise on our planet

135
00:04:57,670 --> 00:04:55,280
how might life arise on other planets

136
00:05:00,710 --> 00:04:57,680
how might we find it and and how do we

137
00:05:01,990 --> 00:05:00,720
understand the evolution of that life

138
00:05:03,670 --> 00:05:02,000

now let's see if we get to the slide i

139
00:05:05,670 --> 00:05:03,680
thought was coming next here it is all

140
00:05:08,310 --> 00:05:05,680
right so the first session of the day

141
00:05:09,749 --> 00:05:08,320
is focusing on astro chemistry this is

142
00:05:12,469 --> 00:05:09,759
what i do so these will be a little bit

143
00:05:14,230 --> 00:05:12,479
better than the coming slides uh so i

144
00:05:15,990 --> 00:05:14,240
define astrochemistry to my friends when

145
00:05:18,629 --> 00:05:16,000
they ask is the study of molecules in

146
00:05:20,390 --> 00:05:18,639
space where they are how they got there

147
00:05:22,870 --> 00:05:20,400
and what they're doing all right so

148
00:05:25,749 --> 00:05:22,880
looking out into space and cataloging in

149
00:05:27,830 --> 00:05:25,759
a range of evolutionary stages

150
00:05:30,230 --> 00:05:27,840
what molecules are present and how do

151
00:05:31,350 --> 00:05:30,240
they lead the evolution into subsequent

152
00:05:33,510 --> 00:05:31,360
steps

153
00:05:35,670 --> 00:05:33,520
all right so if you start off all the

154
00:05:38,390 --> 00:05:35,680
way back with a big bang i mean make

155
00:05:40,790 --> 00:05:38,400
molecules and you made hydrogen

156
00:05:42,469 --> 00:05:40,800
helium and a smattering of lithium and

157
00:05:44,070 --> 00:05:42,479
beryllium and that was it

158
00:05:46,230 --> 00:05:44,080
and that was it for a very long time

159
00:05:47,990 --> 00:05:46,240
until the universe expanded and cooled

160
00:05:50,150 --> 00:05:48,000
off and then that hydrogen and helium

161
00:05:52,150 --> 00:05:50,160
condensed down to form the first stars

162
00:05:53,990 --> 00:05:52,160
right and those nuclear furnaces they

163
00:05:55,670 --> 00:05:54,000

fuse the hydrogen into helium and into

164
00:05:57,830 --> 00:05:55,680
heavier elements until the stars

165
00:05:59,670 --> 00:05:57,840
themselves died out went boom and

166
00:06:02,710 --> 00:05:59,680
distributed heavier and heavier elements

167
00:06:05,670 --> 00:06:02,720
into the cosmos and when those

168
00:06:07,350 --> 00:06:05,680
boom clouds right the remnants of these

169
00:06:08,870 --> 00:06:07,360
expanded enough and cooled off enough

170
00:06:10,469 --> 00:06:08,880
again that hydrogen could start to

171
00:06:13,670 --> 00:06:10,479
condense itself

172
00:06:15,350 --> 00:06:13,680
form the first molecule h2 all right and

173
00:06:16,150 --> 00:06:15,360
then start a chain of reactions from

174
00:06:17,909 --> 00:06:16,160
there

175
00:06:20,629 --> 00:06:17,919
and then you can trace that evolution

176
00:06:21,909 --> 00:06:20,639
from those early molecular clouds

177
00:06:24,070 --> 00:06:21,919
through the formation of subsequent

178
00:06:25,909 --> 00:06:24,080
stars which process heavier and heavier

179
00:06:28,150 --> 00:06:25,919
elements right and make more and more

180
00:06:32,629 --> 00:06:28,160
complex molecules as they condense out

181
00:06:34,710 --> 00:06:32,639
and eventually form solar systems and us

182
00:06:36,150 --> 00:06:34,720
and the study of the chemistry tracing

183
00:06:39,029 --> 00:06:36,160
through all of these these molecules is

184
00:06:40,309 --> 00:06:39,039
what astrochemistry is so astrochemistry

185
00:06:41,430 --> 00:06:40,319
is a field

186
00:06:43,990 --> 00:06:41,440
actually

187
00:06:45,670 --> 00:06:44,000
you go all the way back to 1937 which

188
00:06:48,230 --> 00:06:45,680

doesn't seem very far it's a very young

189
00:06:51,110 --> 00:06:48,240
field the first molecule wasn't detected

190
00:06:53,270 --> 00:06:51,120
in space until 1937. it's the ch

191
00:06:56,469 --> 00:06:53,280
molecule and then

192
00:06:58,390 --> 00:06:56,479
between 1940 and 1963 we only found

193
00:07:01,189 --> 00:06:58,400
three more all right

194
00:07:03,589 --> 00:07:01,199
cn ch plus and oh

195
00:07:05,909 --> 00:07:03,599
it wasn't until the 60s and this is when

196
00:07:07,909 --> 00:07:05,919
radio telescopes and infrared telescopes

197
00:07:10,150 --> 00:07:07,919
really took off in their evolution in

198
00:07:12,230 --> 00:07:10,160
technology sensitivity and resolution

199
00:07:15,110 --> 00:07:12,240
that allowed us to look further deeper

200
00:07:18,070 --> 00:07:15,120
into these clouds and we found 59 more

201
00:07:18,870 --> 00:07:18,080
molecules in the span of oh what's this

202
00:07:20,469 --> 00:07:18,880
here

203
00:07:22,309 --> 00:07:20,479
20 some odd years

204
00:07:23,830 --> 00:07:22,319
this is the real birth place of astro

205
00:07:25,430 --> 00:07:23,840
chemistry this is where it emerged as a

206
00:07:27,670 --> 00:07:25,440
discipline and people started using this

207
00:07:30,230 --> 00:07:27,680
actual word and since the 80s we've

208
00:07:32,550 --> 00:07:30,240
detected more than 110 more molecules so

209
00:07:34,870 --> 00:07:32,560
now there's over 180 individual

210
00:07:36,870 --> 00:07:34,880
molecules this is not counting isotopes

211
00:07:39,510 --> 00:07:36,880
all right this is just regular molecular

212
00:07:41,670 --> 00:07:39,520
species detected in interstellar space

213
00:07:44,070 --> 00:07:41,680

just floating out there in clouds these

214
00:07:46,550 --> 00:07:44,080
are very complex molecules more than 10

215
00:07:48,870 --> 00:07:46,560
atoms in some cases and in

216
00:07:52,309 --> 00:07:48,880
special cases with buckyballs c60 and

217
00:07:53,830 --> 00:07:52,319
c70 right is it dozens of atoms floating

218
00:07:55,670 --> 00:07:53,840
out in space that have come together in

219
00:07:59,110 --> 00:07:55,680
the vacuum of space and they're doing

220
00:08:00,390 --> 00:07:59,120
chemistry i think that's really cool

221
00:08:02,550 --> 00:08:00,400
so

222
00:08:03,990 --> 00:08:02,560
the astrochemistry itself can be broken

223
00:08:05,670 --> 00:08:04,000
down into three sub disciplines and

224
00:08:07,670 --> 00:08:05,680
you'll get a little bit of all three of

225
00:08:09,270 --> 00:08:07,680
these today which is really cool in four

226
00:08:11,430 --> 00:08:09,280
talks this morning you're gonna get some

227
00:08:13,350 --> 00:08:11,440
representative uh from each of these in

228
00:08:15,909 --> 00:08:13,360
one way or the other laboratory

229
00:08:16,950 --> 00:08:15,919
astrophysics and see there's mark go oh

230
00:08:19,110 --> 00:08:16,960
wrong one

231
00:08:21,350 --> 00:08:19,120
there's marco up there

232
00:08:23,749 --> 00:08:21,360
over one of our laser systems in the lab

233
00:08:25,830 --> 00:08:23,759
all right so if you want to compare

234
00:08:28,710 --> 00:08:25,840
your observations that you're taking

235
00:08:30,230 --> 00:08:28,720
with the telescope

236
00:08:31,589 --> 00:08:30,240
to figure out what molecules you're

237
00:08:33,589 --> 00:08:31,599
seeing you have to actually first study

238
00:08:35,909 --> 00:08:33,599

those molecules in the lab all right so

239
00:08:37,509 --> 00:08:35,919
you have a reference to identify oh this

240
00:08:39,190 --> 00:08:37,519
transition showing up at this frequency

241
00:08:40,630 --> 00:08:39,200
is coming from this molecule so that's

242
00:08:43,269 --> 00:08:40,640
what you do in the lab the very most

243
00:08:45,350 --> 00:08:43,279
basic types of laboratory astrophysics

244
00:08:47,670 --> 00:08:45,360
we can go further than that

245
00:08:50,310 --> 00:08:47,680
if you use your astronomy and you

246
00:08:51,910 --> 00:08:50,320
identify that there are molecules x y

247
00:08:53,750 --> 00:08:51,920
and z and various abundances and

248
00:08:56,070 --> 00:08:53,760
temperatures and densities in these

249
00:08:58,870 --> 00:08:56,080
sources right then you might want to

250
00:09:01,509 --> 00:08:58,880
know well what can i make from those

251
00:09:04,070 --> 00:09:01,519
all right so we give that information to

252
00:09:05,670 --> 00:09:04,080
astrochemical modelers and they say well

253
00:09:08,790 --> 00:09:05,680
that's fantastic you told me what we

254
00:09:10,550 --> 00:09:08,800
have but how do they react so the

255
00:09:11,750 --> 00:09:10,560
laboratory astrophysicists go back and

256
00:09:13,269 --> 00:09:11,760
they put these things together in a

257
00:09:15,110 --> 00:09:13,279
reaction chamber and they give you rate

258
00:09:17,430 --> 00:09:15,120
constants and energy barriers and they

259
00:09:19,670 --> 00:09:17,440
say well they react to form this

260
00:09:22,150 --> 00:09:19,680
molecule this fast with this kind of

261
00:09:24,230 --> 00:09:22,160
reaction energy the modelers put all

262
00:09:26,230 --> 00:09:24,240
these into complex chemical codes so

263
00:09:28,790 --> 00:09:26,240

hundreds of molecules and thousands of

264
00:09:30,710 --> 00:09:28,800
reactions it's a giant network vast

265
00:09:32,630 --> 00:09:30,720
computer resources right and they just

266
00:09:33,829 --> 00:09:32,640
step it through in time and they say

267
00:09:35,350 --> 00:09:33,839
well

268
00:09:36,710 --> 00:09:35,360
you have these molecules these are going

269
00:09:38,710 --> 00:09:36,720
to make a high abundance of this

270
00:09:40,470 --> 00:09:38,720
molecule you should go look for that we

271
00:09:42,070 --> 00:09:40,480
have astronomers say well we don't know

272
00:09:43,910 --> 00:09:42,080
where that is it's the laboratory

273
00:09:45,670 --> 00:09:43,920
astrophysicists so we do we can find

274
00:09:47,190 --> 00:09:45,680
that and the cycle just keeps repeating

275
00:09:49,430 --> 00:09:47,200
itself and they feed back into one

276
00:09:52,310 --> 00:09:49,440
another and eventually you start to form

277
00:09:54,310 --> 00:09:52,320
this large picture of complex chemistry

278
00:09:56,870 --> 00:09:54,320
and a source

279
00:09:58,470 --> 00:09:56,880
so why do we i hope this is a slide next

280
00:10:01,269 --> 00:09:58,480
yeah why do we care

281
00:10:02,630 --> 00:10:01,279
this is a picture of a protein

282
00:10:04,790 --> 00:10:02,640
something you might see in your head in

283
00:10:06,550 --> 00:10:04,800
your food last night it's just a cartoon

284
00:10:07,829 --> 00:10:06,560
sketch but if we zoom in here on one of

285
00:10:09,269 --> 00:10:07,839
these little uh

286
00:10:10,550 --> 00:10:09,279
pieces right

287
00:10:12,389 --> 00:10:10,560
these proteins are just made up of

288
00:10:14,550 --> 00:10:12,399

sequences of amino acids as i'm sure

289
00:10:16,150 --> 00:10:14,560
most people know right and

290
00:10:19,750 --> 00:10:16,160
they have different structures there's

291
00:10:21,430 --> 00:10:19,760
glycine and alanine and glutamic acid

292
00:10:22,870 --> 00:10:21,440
all in sequence here

293
00:10:24,150 --> 00:10:22,880
and it's the ordering of these sequences

294
00:10:26,230 --> 00:10:24,160
that builds up the function of the

295
00:10:27,590 --> 00:10:26,240
different proteins into our bodies

296
00:10:30,790 --> 00:10:27,600
we'll come back to why i picked these

297
00:10:33,990 --> 00:10:31,590
so

298
00:10:34,870 --> 00:10:34,000
how do you make

299
00:10:37,350 --> 00:10:34,880
these

300
00:10:38,069 --> 00:10:37,360
complex molecules that that make up life

301
00:10:39,910 --> 00:10:38,079
well

302
00:10:42,150 --> 00:10:39,920
one of the earliest thoughts back in the

303
00:10:43,990 --> 00:10:42,160
50s as i'm sure you've all familiar is

304
00:10:46,470 --> 00:10:44,000
the miliuri synthesis right start with

305
00:10:48,870 --> 00:10:46,480
basic molecules carbon dioxide

306
00:10:50,069 --> 00:10:48,880
water ammonia on an early environment

307
00:10:51,269 --> 00:10:50,079
and you just strike it with lightning

308
00:10:52,949 --> 00:10:51,279
over and over and over and you put

309
00:10:55,190 --> 00:10:52,959
energy into the system and eventually it

310
00:10:57,590 --> 00:10:55,200
builds up some complexity

311
00:10:59,590 --> 00:10:57,600
and whether or not this actually works

312
00:11:01,110 --> 00:10:59,600
on earth has gone back and forth over

313
00:11:03,110 --> 00:11:01,120

the years as we learn more about what

314
00:11:04,790 --> 00:11:03,120
our atmosphere was like

315
00:11:06,310 --> 00:11:04,800
but this is this is one possibility

316
00:11:08,150 --> 00:11:06,320
start with the

317
00:11:11,030 --> 00:11:08,160
simple molecules on earth and just hit

318
00:11:17,350 --> 00:11:14,470
another possibility was raised

319
00:11:19,269 --> 00:11:17,360
once this happened september 28 1969 in

320
00:11:21,590 --> 00:11:19,279
a little town called murchison in

321
00:11:23,670 --> 00:11:21,600
australia the murchison meteorite

322
00:11:25,750 --> 00:11:23,680
impacted and we were lucky because the

323
00:11:27,509 --> 00:11:25,760
residents of the town saw this meteorite

324
00:11:29,350 --> 00:11:27,519
strike and they immediately went out and

325
00:11:30,949 --> 00:11:29,360
started collecting samples so before

326
00:11:32,389 --> 00:11:30,959
these things could get contaminated too

327
00:11:34,389 --> 00:11:32,399
much by their environment they were

328
00:11:36,710 --> 00:11:34,399
isolated by the townsfolk

329
00:11:38,870 --> 00:11:36,720
and then kept waiting in freezers in

330
00:11:40,790 --> 00:11:38,880
some cases for scientists to come up and

331
00:11:42,710 --> 00:11:40,800
and get pristine samples of them so we

332
00:11:44,550 --> 00:11:42,720
have pristine samples from this purchase

333
00:11:47,110 --> 00:11:44,560
and meteorite so

334
00:11:48,310 --> 00:11:47,120
shortly thereafter somebody just scraped

335
00:11:50,630 --> 00:11:48,320
some of this off dissolved it in some

336
00:11:53,190 --> 00:11:50,640
water and stuck it in a

337
00:11:55,350 --> 00:11:53,200
mass spectrometer gcms

338
00:11:58,230 --> 00:11:55,360

and this is what they found

339
00:12:00,230 --> 00:11:58,240
alanine glycine glutamic acid right

340
00:12:01,590 --> 00:12:00,240
those amino acids that make up that

341
00:12:04,949 --> 00:12:01,600
protein that i showed you on the

342
00:12:07,430 --> 00:12:04,959
previous slide found in a meteorite a

343
00:12:09,670 --> 00:12:07,440
pristine remnant of the early solar

344
00:12:11,509 --> 00:12:09,680
system these are not contaminants we

345
00:12:14,069 --> 00:12:11,519
know from the isotopic ratios this does

346
00:12:16,310 --> 00:12:14,079
not arise on earth right so these amino

347
00:12:19,190 --> 00:12:16,320
acids these building blocks of proteins

348
00:12:20,470 --> 00:12:19,200
of us are found in space

349
00:12:22,389 --> 00:12:20,480
long before they are on the earth that's

350
00:12:25,269 --> 00:12:22,399
really cool to me

351
00:12:27,110 --> 00:12:25,279
all right so another possibility here is

352
00:12:29,590 --> 00:12:27,120
that well what if we didn't need the

353
00:12:32,710 --> 00:12:29,600
military synthesis to make

354
00:12:34,150 --> 00:12:32,720
any or maybe not all of our amino acids

355
00:12:37,030 --> 00:12:34,160
what if it happened

356
00:12:40,310 --> 00:12:37,040
during delivery processes well there's

357
00:12:42,629 --> 00:12:40,320
been uh work uh

358
00:12:44,870 --> 00:12:42,639
to uh to look at whether or not well you

359
00:12:47,190 --> 00:12:44,880
start with the simple molecules in the

360
00:12:49,509 --> 00:12:47,200
comet or the meteorite

361
00:12:51,030 --> 00:12:49,519
and then when it impacts the earth right

362
00:12:53,110 --> 00:12:51,040
there's intense pressure and heat that's

363
00:12:55,590 --> 00:12:53,120

generated at that impact and that's just

364
00:12:57,829 --> 00:12:55,600
the same thing as a lightning strike for

365
00:12:58,949 --> 00:12:57,839
better or less right and so that it puts

366
00:13:01,269 --> 00:12:58,959
energy into the system and you

367
00:13:02,870 --> 00:13:01,279
synthesize all of your biomolecules all

368
00:13:04,870 --> 00:13:02,880
at the moment of impact and of course

369
00:13:06,310 --> 00:13:04,880
the other possibility is well maybe they

370
00:13:08,389 --> 00:13:06,320
were formed in the meteorite of the

371
00:13:10,629 --> 00:13:08,399
comet beforehand and they just survived

372
00:13:12,069 --> 00:13:10,639
impact and that actually works too

373
00:13:14,550 --> 00:13:12,079
people have done these experiments in

374
00:13:15,910 --> 00:13:14,560
labs just slamming amino acids at high

375
00:13:17,750 --> 00:13:15,920
pressures and temperatures and they see

376
00:13:19,590 --> 00:13:17,760
that they survive

377
00:13:21,910 --> 00:13:19,600
right so there's more possibilities for

378
00:13:22,949 --> 00:13:21,920
the seating of this prebiotic material

379
00:13:24,790 --> 00:13:22,959
on earth

380
00:13:26,470 --> 00:13:24,800
than we had originally thought these are

381
00:13:28,389 --> 00:13:26,480
very recent papers this one in

382
00:13:30,790 --> 00:13:28,399
particular and they've just started some

383
00:13:34,949 --> 00:13:30,800
experimental work on this this is a

384
00:13:39,269 --> 00:13:37,030
there's also been some independent

385
00:13:41,750 --> 00:13:39,279
confirmation that these things actually

386
00:13:43,190 --> 00:13:41,760
exist right so i don't know how many of

387
00:13:45,430 --> 00:13:43,200
you are familiar with the stardust

388
00:13:47,110 --> 00:13:45,440

mission but we nasa took a satellite and

389
00:13:49,030 --> 00:13:47,120
flew it through the tail of a comet

390
00:13:50,710 --> 00:13:49,040
right this is just passing through the

391
00:13:52,550 --> 00:13:50,720
ice and the gas and the dust which is

392
00:13:54,790 --> 00:13:52,560
coming off the tail of this comet as it

393
00:13:56,710 --> 00:13:54,800
passes by the sun and gets burnt off

394
00:13:58,389 --> 00:13:56,720
they collected the stuff that came off

395
00:14:00,069 --> 00:13:58,399
shot it back we picked it up out of the

396
00:14:01,509 --> 00:14:00,079
desert and we found

397
00:14:04,629 --> 00:14:01,519
glycine

398
00:14:07,910 --> 00:14:04,639
it is

399
00:14:09,430 --> 00:14:07,920
uh in this sample so this is even more

400
00:14:10,949 --> 00:14:09,440
pristine of a remnant from the early

401
00:14:12,389 --> 00:14:10,959
solar system than that meteorite that

402
00:14:14,710 --> 00:14:12,399
impacted there's no chance for earth

403
00:14:17,110 --> 00:14:14,720
contamination here all right

404
00:14:18,870 --> 00:14:17,120
glycine is out there

405
00:14:20,389 --> 00:14:18,880
so one of the big questions in

406
00:14:23,269 --> 00:14:20,399
astrochemistry

407
00:14:24,629 --> 00:14:23,279
uh is how do you get from the simple

408
00:14:26,470 --> 00:14:24,639
molecules

409
00:14:28,949 --> 00:14:26,480
formed in these molecular clouds after

410
00:14:31,910 --> 00:14:28,959
the stars have chewed up those hydrogen

411
00:14:34,870 --> 00:14:31,920
helium elements spat them out to the

412
00:14:36,150 --> 00:14:34,880
amino acids that we see on earth

413
00:14:38,870 --> 00:14:36,160

right and there's different

414
00:14:39,990 --> 00:14:38,880
possibilities here so

415
00:14:41,430 --> 00:14:40,000
there we go

416
00:14:43,189 --> 00:14:41,440
right one is you just incorporate the

417
00:14:45,030 --> 00:14:43,199
simple molecules onto the planet as we

418
00:14:47,269 --> 00:14:45,040
talked about either while the planet is

419
00:14:48,710 --> 00:14:47,279
forming just secretes uh during the

420
00:14:50,870 --> 00:14:48,720
older solar system or it gets delivered

421
00:14:52,069 --> 00:14:50,880
by those comets do miller uric synthesis

422
00:14:54,150 --> 00:14:52,079
there you go

423
00:14:54,870 --> 00:14:54,160
another is that those simple molecules

424
00:14:57,110 --> 00:14:54,880
get

425
00:14:59,269 --> 00:14:57,120
incorporated into the cometary ice that

426
00:15:02,069 --> 00:14:59,279
comet impacts the planet and that impact

427
00:15:04,069 --> 00:15:02,079
event generates the amino acids

428
00:15:05,750 --> 00:15:04,079
all right

429
00:15:08,550 --> 00:15:05,760
or let's see you could go the other way

430
00:15:10,230 --> 00:15:08,560
here right uh the simple molecules

431
00:15:13,110 --> 00:15:10,240
impact and then undergo military

432
00:15:14,790 --> 00:15:13,120
synthesis some combination for two

433
00:15:16,069 --> 00:15:14,800
we can go the other route and say the

434
00:15:17,990 --> 00:15:16,079
simple molecules are going to stay in

435
00:15:19,829 --> 00:15:18,000
the gas phase the entire time and

436
00:15:21,990 --> 00:15:19,839
they're just going to react do chemistry

437
00:15:23,910 --> 00:15:22,000
in the cloud form amino acids just

438
00:15:25,590 --> 00:15:23,920

floating around in space and incorporate

439
00:15:27,590 --> 00:15:25,600
those into the planets

440
00:15:29,350 --> 00:15:27,600
you can also have them incorporated into

441
00:15:31,509 --> 00:15:29,360
the ice of the of the comet and then do

442
00:15:33,590 --> 00:15:31,519
reactions in the solid state in the ice

443
00:15:35,189 --> 00:15:33,600
the molecular water ice on cometary

444
00:15:37,750 --> 00:15:35,199
surfaces and then impact them we know

445
00:15:39,350 --> 00:15:37,760
that the amino acids survive there

446
00:15:41,189 --> 00:15:39,360
or you can go even a more securities

447
00:15:43,189 --> 00:15:41,199
route take simple molecules put them in

448
00:15:45,189 --> 00:15:43,199
an interstellar ice on the surface of

449
00:15:47,910 --> 00:15:45,199
micron-sized dust grains

450
00:15:50,310 --> 00:15:47,920
all right form complex molecules there

451
00:15:53,910 --> 00:15:50,320
have all of that dust accrete form a

452
00:15:55,749 --> 00:15:53,920
comet and then impact a planet that way

453
00:15:57,430 --> 00:15:55,759
so we know a few things about about

454
00:15:59,670 --> 00:15:57,440
these different reaction pathways and

455
00:16:01,749 --> 00:15:59,680
one of them is that this route here

456
00:16:04,230 --> 00:16:01,759
forming complex molecules like glycine

457
00:16:06,790 --> 00:16:04,240
in the gas phase just doesn't work

458
00:16:08,629 --> 00:16:06,800
right laboratory experiments proved that

459
00:16:10,150 --> 00:16:08,639
there's just too much of a reaction

460
00:16:12,870 --> 00:16:10,160
barrier to make anything more

461
00:16:14,550 --> 00:16:12,880
complicated than about methyl formate

462
00:16:16,310 --> 00:16:14,560
as long as it's an organic molecule you

463
00:16:18,069 --> 00:16:16,320

can build up long chain hydrocarbons

464
00:16:20,310 --> 00:16:18,079
just carbon and hydrogen and some

465
00:16:22,069 --> 00:16:20,320
nitrogen that's fine or buckyballs but

466
00:16:24,150 --> 00:16:22,079
the things that we need for life they're

467
00:16:27,110 --> 00:16:24,160
just not energetically favorable above

468
00:16:29,110 --> 00:16:27,120
say about eight or nine atoms total uh

469
00:16:31,189 --> 00:16:29,120
with few exceptions so you have to make

470
00:16:33,829 --> 00:16:31,199
these things going through

471
00:16:36,629 --> 00:16:33,839
solid state reaction chemistry at some

472
00:16:37,990 --> 00:16:36,639
point either in isis or once you get to

473
00:16:39,509 --> 00:16:38,000
the earth

474
00:16:41,430 --> 00:16:39,519
and the other thing we know is that from

475
00:16:44,790 --> 00:16:41,440
the stardust mission there are complex

476
00:16:47,030 --> 00:16:44,800
molecules present in these cometary ices

477
00:16:49,110 --> 00:16:47,040
right so now for astrochemists the

478
00:16:51,430 --> 00:16:49,120
question is

479
00:16:53,430 --> 00:16:51,440
where along this path do you actually

480
00:16:55,670 --> 00:16:53,440
make these complex molecules and what's

481
00:16:56,870 --> 00:16:55,680
the chemistry necessary to do it all

482
00:16:58,310 --> 00:16:56,880
right because once you understand that

483
00:17:00,870 --> 00:16:58,320
then you can start looking at these

484
00:17:03,030 --> 00:17:00,880
different sources all right so molecular

485
00:17:05,270 --> 00:17:03,040
clouds or protoplanetary disks

486
00:17:07,110 --> 00:17:05,280
forming star systems and say which one

487
00:17:09,270 --> 00:17:07,120
of these is eventually going to lead to

488
00:17:11,350 --> 00:17:09,280

the formation of life what's the place

489
00:17:12,549 --> 00:17:11,360
we should be looking for

490
00:17:14,710 --> 00:17:12,559
based on the chemistry that we're

491
00:17:16,390 --> 00:17:14,720
observing to go look for life in other

492
00:17:19,270 --> 00:17:16,400
worlds

493
00:17:20,789 --> 00:17:19,280
all right so moving on to planetary

494
00:17:22,470 --> 00:17:20,799
solar system bodies here this is the

495
00:17:24,470 --> 00:17:22,480
wishy wash report of the

496
00:17:26,710 --> 00:17:24,480
portion of the talk uh the reason we're

497
00:17:28,549 --> 00:17:26,720
interested in that is this really uh

498
00:17:30,789 --> 00:17:28,559
pretty picture here from our proposal at

499
00:17:32,630 --> 00:17:30,799
rfg i put it in there because it looks

500
00:17:35,430 --> 00:17:32,640
nice is the grand prismatic spring in

501
00:17:37,990 --> 00:17:35,440
yellowstone right this is a really

502
00:17:39,270 --> 00:17:38,000
unfriendly environment for for life as

503
00:17:41,430 --> 00:17:39,280
we really

504
00:17:43,909 --> 00:17:41,440
think of it ourselves but there's tons

505
00:17:46,230 --> 00:17:43,919
of microorganisms living in here in this

506
00:17:47,750 --> 00:17:46,240
extreme harsh environment and so this

507
00:17:49,909 --> 00:17:47,760
leads us to thinking well what if these

508
00:17:52,950 --> 00:17:49,919
microorganisms can live in other harsh

509
00:17:54,390 --> 00:17:52,960
environments in our solar system

510
00:17:56,789 --> 00:17:54,400
like this little guy here if you've been

511
00:17:58,710 --> 00:17:56,799
watching cosmos the tardigrade right

512
00:18:01,110 --> 00:17:58,720
this is apparently neil degrasse tyson's

513
00:18:04,470 --> 00:18:01,120

favorite little water bear

514
00:18:06,549 --> 00:18:04,480
this thing can survive in antarctic ice

515
00:18:08,230 --> 00:18:06,559
it can survive in the vacuum of space it

516
00:18:11,029 --> 00:18:08,240
can survive incredible doses of

517
00:18:12,390 --> 00:18:11,039
radiation it just goes dormant and then

518
00:18:14,310 --> 00:18:12,400
when it gets

519
00:18:15,830 --> 00:18:14,320
a little bit of heat a little bit of uh

520
00:18:17,430 --> 00:18:15,840
nutrients it just picks right back up

521
00:18:19,909 --> 00:18:17,440
where it was going after

522
00:18:21,750 --> 00:18:19,919
decades right these things can survive

523
00:18:23,350 --> 00:18:21,760
anything so if they can survive anything

524
00:18:26,549 --> 00:18:23,360
on earth why can't they survive anything

525
00:18:29,029 --> 00:18:26,559
or something like them on another planet

526
00:18:31,510 --> 00:18:29,039
there's our solar system pluto should be

527
00:18:34,310 --> 00:18:31,520
out here uh

528
00:18:36,150 --> 00:18:34,320
today the talks fortunately for me only

529
00:18:37,510 --> 00:18:36,160
focus on a very small region of our

530
00:18:40,789 --> 00:18:37,520
solar system

531
00:18:42,950 --> 00:18:40,799
mars and europa a satellite of jupiter

532
00:18:44,310 --> 00:18:42,960
here so as i said i just went to

533
00:18:46,230 --> 00:18:44,320
wikipedia and looked up things that i

534
00:18:47,669 --> 00:18:46,240
found fun about mars in europa so we'll

535
00:18:49,430 --> 00:18:47,679
just blast through a few of these here

536
00:18:51,270 --> 00:18:49,440
and then and we'll open up the florida

537
00:18:54,870 --> 00:18:51,280
questions so there's mars

538
00:18:56,710 --> 00:18:54,880

uh mars is about half the size of earth

539
00:19:00,630 --> 00:18:56,720
never seen the comparison

540
00:19:03,270 --> 00:19:00,640
uh it also has a a slightly offs

541
00:19:05,270 --> 00:19:03,280
kilter orbit from earth right so we

542
00:19:08,150 --> 00:19:05,280
actually pass closer and farther away

543
00:19:10,310 --> 00:19:08,160
from mars every two years or so

544
00:19:13,029 --> 00:19:10,320
the closest approach to mars i think was

545
00:19:14,870 --> 00:19:13,039
a couple years ago but in 2018 here

546
00:19:17,110 --> 00:19:14,880
we're actually only going to be

547
00:19:19,510 --> 00:19:17,120
57 million kilometers away that's pretty

548
00:19:21,590 --> 00:19:19,520
darn close right so this is when they

549
00:19:23,750 --> 00:19:21,600
aim missions to arrive

550
00:19:25,669 --> 00:19:23,760
right so you launch a satellite so that

551
00:19:28,070 --> 00:19:25,679
it takes the shortest path possible to

552
00:19:31,669 --> 00:19:28,080
get to mars and it requires the least uh

553
00:19:32,710 --> 00:19:31,679
change in its velocity to get there

554
00:19:35,029 --> 00:19:32,720
so

555
00:19:37,029 --> 00:19:35,039
oh this is fun what's it like on mars

556
00:19:39,270 --> 00:19:37,039
right now according to the mars science

557
00:19:41,750 --> 00:19:39,280
laboratory it's september at least the

558
00:19:45,110 --> 00:19:41,760
equivalent weather to earth uh it's

559
00:19:48,230 --> 00:19:45,120
about -75 c where curiosity is hanging

560
00:19:49,150 --> 00:19:48,240
out uh and the pressure right there is

561
00:19:52,310 --> 00:19:49,160
about

562
00:19:54,549 --> 00:19:52,320
0.0073 atmospheres so we're talking

563
00:19:56,789 --> 00:19:54,559

about one percent

564
00:19:59,190 --> 00:19:56,799
of the earth's atmospheric pressure so

565
00:20:01,190 --> 00:19:59,200
despite everybody talking about you know

566
00:20:02,390 --> 00:20:01,200
complex atmospheric conditions on mars

567
00:20:04,470 --> 00:20:02,400
you have to realize that this this

568
00:20:06,310 --> 00:20:04,480
density is actually very low compared to

569
00:20:07,990 --> 00:20:06,320
what we're used to here even though

570
00:20:09,430 --> 00:20:08,000
there's still complex processes

571
00:20:10,950 --> 00:20:09,440
occurring there

572
00:20:13,190 --> 00:20:10,960
and there's the comparison to earth at

573
00:20:15,590 --> 00:20:13,200
30 000 feet that most of you flew at

574
00:20:17,510 --> 00:20:15,600
recently

575
00:20:19,029 --> 00:20:17,520
click there we go

576
00:20:20,470 --> 00:20:19,039
composition of the martian atmosphere

577
00:20:23,190 --> 00:20:20,480
which i'm sure somebody will talk about

578
00:20:25,430 --> 00:20:23,200
in more detail later mostly co2 little

579
00:20:27,350 --> 00:20:25,440
argon a little nitrogen as opposed to us

580
00:20:29,350 --> 00:20:27,360
mostly nitrogen right

581
00:20:32,070 --> 00:20:29,360
all right the different missions that

582
00:20:35,350 --> 00:20:32,080
have been to mars we have the mars

583
00:20:37,190 --> 00:20:35,360
reconnaissance orbiter uh mars express

584
00:20:38,950 --> 00:20:37,200
the spirit and opportunity rovers at

585
00:20:41,590 --> 00:20:38,960
least one of which is now permanently

586
00:20:42,789 --> 00:20:41,600
stationary very sad got stuck in some

587
00:20:45,430 --> 00:20:42,799
loose soil

588
00:20:48,149 --> 00:20:45,440

maven should arrive next month i believe

589
00:20:50,149 --> 00:20:48,159
just a couple of weeks from now uh the

590
00:20:52,310 --> 00:20:50,159
mars orbiter i believe it's called and

591
00:20:53,750 --> 00:20:52,320
the mars science laboratory

592
00:20:54,789 --> 00:20:53,760
so each of these carries a suite of

593
00:20:57,110 --> 00:20:54,799
instruments on them they can do

594
00:20:58,630 --> 00:20:57,120
different things uh

595
00:21:00,149 --> 00:20:58,640
i will put up the different instruments

596
00:21:01,830 --> 00:21:00,159
here and just highlight the ones that i

597
00:21:03,750 --> 00:21:01,840
think we're going to hear the most about

598
00:21:05,830 --> 00:21:03,760
over the next few days or that that i

599
00:21:07,590 --> 00:21:05,840
have heard the most about recently and

600
00:21:09,990 --> 00:21:07,600
on the mars reconnaissance over there

601
00:21:12,070 --> 00:21:10,000
that one is definitely chrism here all

602
00:21:13,590 --> 00:21:12,080
right so this is a reflectance infrared

603
00:21:15,110 --> 00:21:13,600
spectrometer so it's just looking at the

604
00:21:16,710 --> 00:21:15,120
light that is impacting the surface of

605
00:21:19,909 --> 00:21:16,720
the planet or coming off the surface of

606
00:21:22,149 --> 00:21:19,919
the planet takes the spectrum in the

607
00:21:24,470 --> 00:21:22,159
near and mid infrared region now in

608
00:21:26,710 --> 00:21:24,480
these regions this is very sensitive to

609
00:21:28,390 --> 00:21:26,720
the physical structure of the minerals

610
00:21:30,070 --> 00:21:28,400
on the surface so it gives you an idea

611
00:21:32,149 --> 00:21:30,080
of the hydration state of these minerals

612
00:21:35,190 --> 00:21:32,159
and the different types of species

613
00:21:36,549 --> 00:21:35,200

which map out the entirety of the planet

614
00:21:37,990 --> 00:21:36,559
all right mars science laboratory can

615
00:21:39,669 --> 00:21:38,000
scoop up some dirt and look at it but

616
00:21:42,230 --> 00:21:39,679
it's limited to where it's at this thing

617
00:21:43,590 --> 00:21:42,240
sweeps huge swaths of the planet to 18

618
00:21:44,710 --> 00:21:43,600
meter resolution which is pretty

619
00:21:46,630 --> 00:21:44,720
impressive

620
00:21:48,390 --> 00:21:46,640
there's also a ground penetrating radar

621
00:21:49,750 --> 00:21:48,400
system on here that i think we'll hear

622
00:21:51,190 --> 00:21:49,760
something about later on in the

623
00:21:51,990 --> 00:21:51,200
conference

624
00:21:54,149 --> 00:21:52,000
uh

625
00:21:56,549 --> 00:21:54,159
complementary to chrism on mars express

626
00:21:58,789 --> 00:21:56,559
is omega so where chrism was 18 meter

627
00:22:01,110 --> 00:21:58,799
resolution omega is 100 meter resolution

628
00:22:02,870 --> 00:22:01,120
and it covers similar ranges so omega is

629
00:22:04,630 --> 00:22:02,880
sweeping out the entire planet at low

630
00:22:06,950 --> 00:22:04,640
resolution and identifying places that

631
00:22:09,029 --> 00:22:06,960
might be of interest to zoom in on with

632
00:22:10,950 --> 00:22:09,039
prism all right to look at rocky

633
00:22:13,190 --> 00:22:10,960
outcroppings and differentiation on the

634
00:22:15,830 --> 00:22:13,200
on the surface

635
00:22:20,630 --> 00:22:15,840
uh mars orbiter here it's called the

636
00:22:22,630 --> 00:22:20,640
mars orbiter uh has a few uh uh

637
00:22:25,669 --> 00:22:22,640
energetic radiation sources detectors

638
00:22:27,750 --> 00:22:25,679

here uh as as well as a visible camera

639
00:22:29,270 --> 00:22:27,760
at a relatively impressive resolution of

640
00:22:30,789 --> 00:22:29,280
18 meters again so it's just taking

641
00:22:31,669 --> 00:22:30,799
pictures of the surface and mapping it

642
00:22:35,750 --> 00:22:31,679
out

643
00:22:37,830 --> 00:22:35,760
and maven which will arrive uh has a

644
00:22:41,190 --> 00:22:37,840
neutral gas and ion mass spectrometer

645
00:22:42,950 --> 00:22:41,200
imaging ultraviolet spectrometer and

646
00:22:44,230 --> 00:22:42,960
energetic particle analyses here this is

647
00:22:46,390 --> 00:22:44,240
going to do a lot of work on the martian

648
00:22:48,230 --> 00:22:46,400
atmosphere and the radiation environment

649
00:22:51,029 --> 00:22:48,240
there

650
00:22:52,390 --> 00:22:51,039
and spirit and opportunity on the planet

651
00:22:54,630 --> 00:22:52,400
as i said they've been there for quite a

652
00:22:55,350 --> 00:22:54,640
while one of them is now stuck

653
00:22:57,110 --> 00:22:55,360
but

654
00:22:58,950 --> 00:22:57,120
they take pictures

655
00:23:01,110 --> 00:22:58,960
they can scrape up rocks they can

656
00:23:03,110 --> 00:23:01,120
measure the magnetic field of mars

657
00:23:04,950 --> 00:23:03,120
they've been invaluable

658
00:23:07,110 --> 00:23:04,960
and then most recently of course is the

659
00:23:08,310 --> 00:23:07,120
mars science laboratory and and one of

660
00:23:09,909 --> 00:23:08,320
the instruments here is the rover

661
00:23:11,270 --> 00:23:09,919
environmental monitoring station that's

662
00:23:13,270 --> 00:23:11,280
where i got the weather forecast for

663
00:23:16,390 --> 00:23:13,280

mars and we'll hear something about that

664
00:23:18,549 --> 00:23:16,400
from uh from somebody soon it also has a

665
00:23:20,149 --> 00:23:18,559
freaking laser attached to its head

666
00:23:21,909 --> 00:23:20,159
all right so you can blow something up

667
00:23:24,789 --> 00:23:21,919
seven meters away and then take the

668
00:23:25,590 --> 00:23:24,799
spectrum of that which is just cool

669
00:23:28,070 --> 00:23:25,600
uh

670
00:23:29,750 --> 00:23:28,080
seven meters this is fantastic

671
00:23:31,430 --> 00:23:29,760
all right moving on to europa in the

672
00:23:33,990 --> 00:23:31,440
last few minutes here

673
00:23:35,750 --> 00:23:34,000
uh satellite of jupiter

674
00:23:37,350 --> 00:23:35,760
it's just a little bit smaller than our

675
00:23:41,510 --> 00:23:37,360
moon not much

676
00:23:45,909 --> 00:23:43,110
well that didn't translate if you were

677
00:23:47,510 --> 00:23:45,919
to measure the density of europa there's

678
00:23:49,430 --> 00:23:47,520
a whole bunch of text here believe it or

679
00:23:51,430 --> 00:23:49,440
not uh

680
00:23:53,029 --> 00:23:51,440
you'd find that it's actually relatively

681
00:23:54,870 --> 00:23:53,039
dense compared to what you might

682
00:23:56,549 --> 00:23:54,880
originally think and that density leads

683
00:23:58,789 --> 00:23:56,559
people to believe that it actually has a

684
00:24:00,230 --> 00:23:58,799
solid or a molten iron core

685
00:24:02,390 --> 00:24:00,240
and then a

686
00:24:05,029 --> 00:24:02,400
water type ocean

687
00:24:06,549 --> 00:24:05,039
right with a silicate mantle so there's

688
00:24:08,149 --> 00:24:06,559

actually a rocky mantle on top of that

689
00:24:10,789 --> 00:24:08,159
core between the core in the ocean and

690
00:24:12,789 --> 00:24:10,799
then a cross device over the top

691
00:24:15,909 --> 00:24:12,799
uh at least according to the papers i

692
00:24:17,269 --> 00:24:15,919
read which were a few years old uh also

693
00:24:19,269 --> 00:24:17,279
oh it's because there's no black

694
00:24:21,190 --> 00:24:19,279
background here for some reason

695
00:24:24,549 --> 00:24:21,200
uh that's gonna be a problem

696
00:24:26,870 --> 00:24:24,559
uh also uh hubble has observed plumes of

697
00:24:29,269 --> 00:24:26,880
water spouting off the surface of this

698
00:24:30,630 --> 00:24:29,279
planet all right now this is a not just

699
00:24:33,190 --> 00:24:30,640
a little bit of water this is ton of

700
00:24:36,149 --> 00:24:33,200
water it comes out in amounts of seven

701
00:24:39,590 --> 00:24:36,159
thousand kilograms every second of water

702
00:24:41,510 --> 00:24:39,600
shooting as high as uh

703
00:24:42,870 --> 00:24:41,520
the himalayan mountains i believe off

704
00:24:44,789 --> 00:24:42,880
the surface of this planet these are

705
00:24:47,029 --> 00:24:44,799
giant plumes of water coming off the

706
00:24:49,669 --> 00:24:47,039
surface europe which is really cool uh

707
00:24:52,070 --> 00:24:49,679
europa's surface is also very smooth

708
00:24:53,510 --> 00:24:52,080
uh and and it's a very young surface and

709
00:24:56,310 --> 00:24:53,520
that's apparently caused by its

710
00:24:59,269 --> 00:24:56,320
interaction with jupiter so jupiter here

711
00:25:01,990 --> 00:24:59,279
induces uh a magnetic field

712
00:25:04,070 --> 00:25:02,000
small one in europe it also exerts

713
00:25:05,669 --> 00:25:04,080

extreme tidal forces on it so it's

714
00:25:07,669 --> 00:25:05,679
constantly reshaping the surface of

715
00:25:09,830 --> 00:25:07,679
europa to be quite smooth and relatively

716
00:25:13,830 --> 00:25:09,840
featureless with the exception of these

717
00:25:15,590 --> 00:25:13,840
things which the word is there lynnae

718
00:25:17,350 --> 00:25:15,600
there were a lot of talks on these last

719
00:25:20,710 --> 00:25:17,360
year at grad con i don't know if we're

720
00:25:22,710 --> 00:25:20,720
going to see a bunch this year these are

721
00:25:23,990 --> 00:25:22,720
off-color bands depressions in the

722
00:25:25,590 --> 00:25:24,000
surface they're

723
00:25:27,350 --> 00:25:25,600
more than 20 kilometers wide in some

724
00:25:28,549 --> 00:25:27,360
cases that's as wide or wider than the

725
00:25:30,870 --> 00:25:28,559
grand canyon

726
00:25:33,669 --> 00:25:30,880
right these are huge crosses across the

727
00:25:35,909 --> 00:25:33,679
surface of europa and one of the leading

728
00:25:39,110 --> 00:25:35,919
theories is that they're caused by

729
00:25:40,789 --> 00:25:39,120
tidal forces from jupiter causing ocean

730
00:25:43,110 --> 00:25:40,799
currents to come up and split the

731
00:25:45,110 --> 00:25:43,120
surface ice right and spread it apart

732
00:25:47,909 --> 00:25:45,120
into these wide chasms and so you have

733
00:25:49,669 --> 00:25:47,919
differentiation in the age of the ice

734
00:25:51,190 --> 00:25:49,679
and also the mineral composition as it's

735
00:25:54,789 --> 00:25:51,200
dragging stuff up from the bottom of the

736
00:25:59,269 --> 00:25:57,750
and as a cartoon from wikipedia again

737
00:26:01,029 --> 00:25:59,279
that ocean that i'm talking about

738
00:26:02,789 --> 00:26:01,039

apparently there is still some debate

739
00:26:04,630 --> 00:26:02,799
whether or not it's actually liquid

740
00:26:05,350 --> 00:26:04,640
under there or whether or not it's just