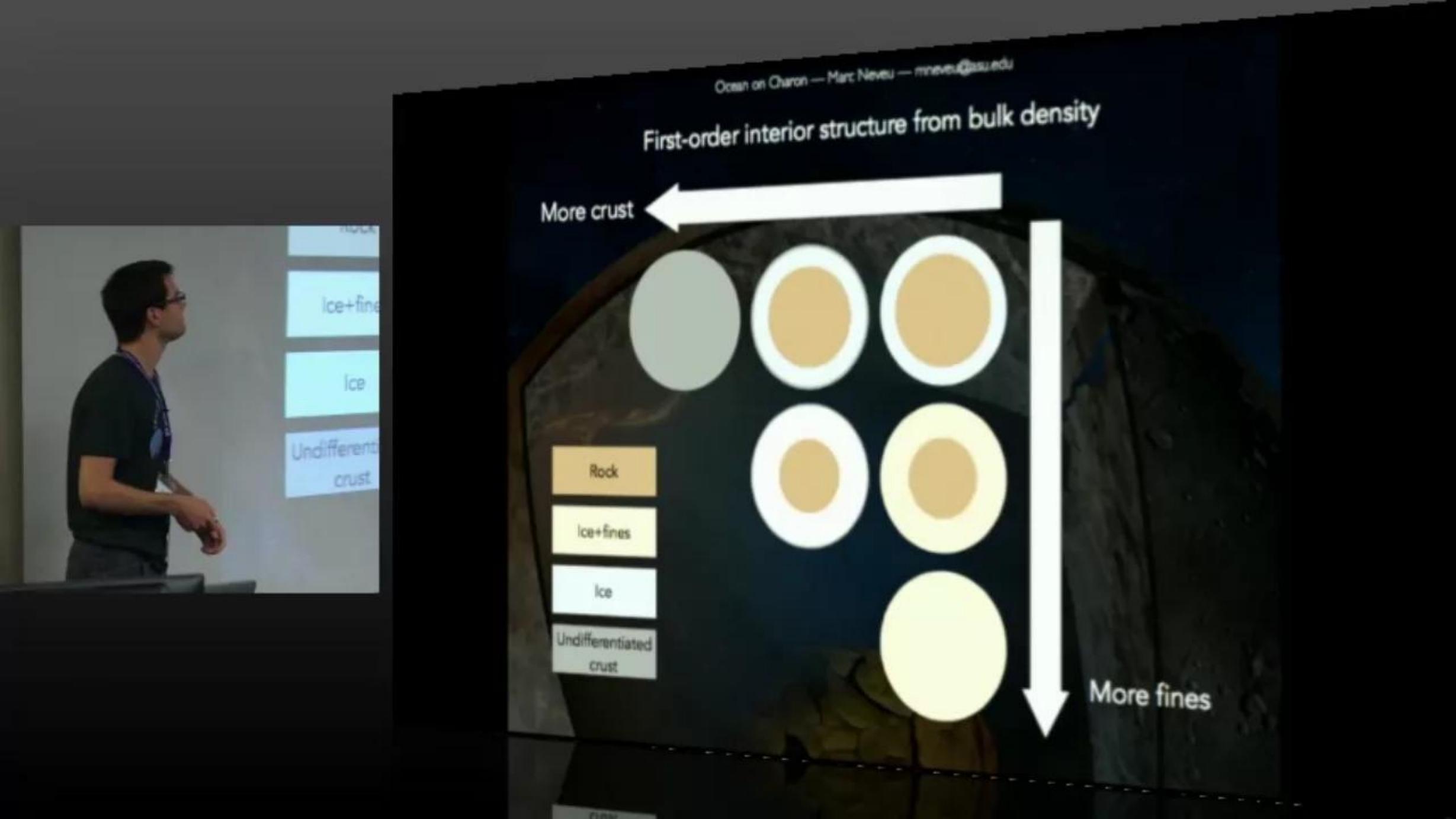
Ocean on Charon — Marc Neveu — mneveu@asu.edu
First-order interior structure from bulk density
More crust
Rock
Ice+fines
Ice
Undifferentiated crust
More fines
Ice+fine
Ice
Undifferent
crust

1
00:00:11,240 --> 00:00:08,930
okay so let's talk about the

2
00:00:14,450 --> 00:00:11,250
astrobiology of karabell objects a

3
00:00:17,180 --> 00:00:14,460
little more i'll focus again on Sharon

4
00:00:20,510 --> 00:00:17,190
specifically for this talk and the

5
00:00:22,660 --> 00:00:20,520
presence of oceans and spoiler alert is

6
00:00:26,660 --> 00:00:22,670
more like past oceans not current oceans

7
00:00:28,189 --> 00:00:26,670
unfortunately but keep in mind that we

8
00:00:30,410 --> 00:00:28,199
know the Pluto sharing system really

9
00:00:32,330 --> 00:00:30,420
well now compared to two other care

10
00:00:35,000 --> 00:00:32,340
about objects but these results again

11
00:00:36,350 --> 00:00:35,010
are applicable to many other places and

12
00:00:38,869 --> 00:00:36,360
the reason why it's so interesting for

13
00:00:41,000 --> 00:00:38,879

astrobiology is that we know of about

14
00:00:43,190 --> 00:00:41,010
say a couple hundred objects you no

15
00:00:45,680 --> 00:00:43,200
larger than 200 kilometers in radius in

16
00:00:48,049 --> 00:00:45,690
the Kuiper belt and that add numbers any

17
00:00:49,910 --> 00:00:48,059
other objects to the same size in our

18
00:00:52,580 --> 00:00:49,920
solar system presumably it's the same

19
00:00:53,900 --> 00:00:52,590
thing in other solar systems as well and

20
00:00:56,029 --> 00:00:53,910
so we might be looking at the most

21
00:00:58,490 --> 00:00:56,039
common type of solid worlds in the

22
00:01:02,560 --> 00:00:58,500
universe and so if we can say something

23
00:01:06,080 --> 00:01:02,570
about the astrobiology it's pretty cool

24
00:01:08,630 --> 00:01:06,090
alright so the Pluto shirin systems it's

25
00:01:10,429 --> 00:01:08,640
about a 40 astronomical units from the

26
00:01:14,840 --> 00:01:10,439
Sun so for people who are not familiar

27
00:01:17,120 --> 00:01:14,850
with this it's pretty far so far that

28
00:01:22,310 --> 00:01:17,130
actually the surface of sharing is only

29
00:01:25,929 --> 00:01:22,320
about 40 Kelvin as Brian mentioned so so

30
00:01:28,130 --> 00:01:25,939
Sharon I'll talk more about its

31
00:01:30,080 --> 00:01:28,140
structural properties its interior its

32
00:01:31,550 --> 00:01:30,090
evolution over time and I think that's a

33
00:01:32,840 --> 00:01:31,560
good complement to the compositional

34
00:01:36,770 --> 00:01:32,850
information we just got from both to

35
00:01:40,280 --> 00:01:36,780
there and sharing so Sharon is about 600

36
00:01:43,069 --> 00:01:40,290
kilometers in radius and it has a

37
00:01:44,840 --> 00:01:43,079
density of the 1.6 grams per cubic

38
00:01:48,260 --> 00:01:44,850

centimeter and that's about between

39
00:01:50,510 --> 00:01:48,270
water or ice and rock and so we think

40
00:01:52,420 --> 00:01:50,520
it's made of a mix of water and rock

41
00:01:54,740 --> 00:01:52,430
because we have nothing better to say

42
00:01:56,170 --> 00:01:54,750
that's pretty good assumption this seems

43
00:01:59,120 --> 00:01:56,180
to be pretty common platforming

44
00:02:01,969 --> 00:01:59,130
materials now Pluto is a little bit

45
00:02:06,980 --> 00:02:01,979
denser 1.8 grams per cubic centimeters

46
00:02:08,900 --> 00:02:06,990
but it's about the same essentially so

47
00:02:10,550 --> 00:02:08,910
Pluto and turn are not alone you've

48
00:02:12,470 --> 00:02:10,560
heard that there are four extra moons in

49
00:02:13,270 --> 00:02:12,480
the system what's very interesting is

50
00:02:15,580 --> 00:02:13,280
that

51
00:02:19,000 --> 00:02:15,590
all moons and pluto and charon all

52
00:02:21,010 --> 00:02:19,010
orbits in the same plane and so rather

53
00:02:23,350 --> 00:02:21,020
than it's done that something about how

54
00:02:26,170 --> 00:02:23,360
this came to be rather than the moon is

55
00:02:27,760 --> 00:02:26,180
just being captured by the system it

56
00:02:29,620 --> 00:02:27,770
looks like the entire thing form from

57
00:02:32,199 --> 00:02:29,630
the same disk and I like a mini solar

58
00:02:34,420 --> 00:02:32,209
system right and so as Brian showed this

59
00:02:36,040 --> 00:02:34,430
is kind of the leading theory or

60
00:02:39,640 --> 00:02:36,050
hypothesis for the formation of the

61
00:02:42,220 --> 00:02:39,650
system and to get this to work you need

62
00:02:44,229 --> 00:02:42,230
to have two presenters collide and the

63
00:02:47,199 --> 00:02:44,239

progenitors are of size intermediate

64
00:02:49,030 --> 00:02:47,209
between between pluto and charon and so

65
00:02:51,449 --> 00:02:49,040
they have to strike I pretty much at the

66
00:02:55,390 --> 00:02:51,459
right speed the right angle but it works

67
00:02:57,280 --> 00:02:55,400
and so what happens is that Pluto tends

68
00:02:59,440 --> 00:02:57,290
to form from the material that was kind

69
00:03:02,430 --> 00:02:59,450
of inside like the cores of these things

70
00:03:05,800 --> 00:03:02,440
and sharing from from the outer material

71
00:03:08,500 --> 00:03:05,810
kind of the outer outer shell okay and

72
00:03:11,620 --> 00:03:08,510
whatever is left in the d'bries form of

73
00:03:13,870 --> 00:03:11,630
this moment so what's interesting here

74
00:03:15,280 --> 00:03:13,880
is that keep in mind Pluto is a little

75
00:03:17,229 --> 00:03:15,290
bit denser than insurance it's a bit

76
00:03:18,610 --> 00:03:17,239
more rock rich and that's telling us

77
00:03:20,680 --> 00:03:18,620
that you know if you deform from the

78
00:03:22,780 --> 00:03:20,690
materials that were inside this /

79
00:03:24,789 --> 00:03:22,790
generators in towards the center the

80
00:03:27,970 --> 00:03:24,799
progenitors must have been more rock

81
00:03:29,860 --> 00:03:27,980
wish here and more I switch here so in

82
00:03:31,840 --> 00:03:29,870
other words they were probably a lil bit

83
00:03:33,490 --> 00:03:31,850
differentiated between rock and ice okay

84
00:03:35,020 --> 00:03:33,500
but it's not to say that they had a

85
00:03:37,300 --> 00:03:35,030
rocky core in an icy shell like you

86
00:03:39,310 --> 00:03:37,310
expect for Europa for example because

87
00:03:41,110 --> 00:03:39,320
otherwise showing would be completely I

88
00:03:42,729 --> 00:03:41,120

see and it's not completely actually has

89
00:03:45,400 --> 00:03:42,739
some rock in it right otherwise you

90
00:03:47,380 --> 00:03:45,410
wouldn't get a density of 1.6 so we have

91
00:03:49,330 --> 00:03:47,390
to come up with a way of having the

92
00:03:52,509 --> 00:03:49,340
progenitors evolved to the point where

93
00:03:54,039 --> 00:03:52,519
they have a partial differentiation

94
00:03:56,229 --> 00:03:54,049
between ice and rock but still keep some

95
00:04:02,710 --> 00:03:56,239
rock on the outside so that was one of

96
00:04:03,789 --> 00:04:02,720
the goals of this work and we've been

97
00:04:06,130 --> 00:04:03,799
trying to understand how this

98
00:04:07,900 --> 00:04:06,140
differentiation process works so

99
00:04:09,370 --> 00:04:07,910
presumably all these objects can a form

100
00:04:14,620 --> 00:04:09,380
from a homogeneous mixture of ice and

101
00:04:16,120 --> 00:04:14,630
rock that then separates and the way to

102
00:04:17,979 --> 00:04:16,130
separate ice cream rock is just to have

103
00:04:19,810 --> 00:04:17,989
going to rock fall through the ice and

104
00:04:21,219 --> 00:04:19,820
sorted by density but to get this to

105
00:04:24,740 --> 00:04:21,229
happen you need the ice to soften

106
00:04:27,560 --> 00:04:24,750
sufficiently or even to melt

107
00:04:29,690 --> 00:04:27,570
this will usually happen at the center

108
00:04:31,360 --> 00:04:29,700
first because the center is the most

109
00:04:34,130 --> 00:04:31,370
insulated place from the frigid surface

110
00:04:36,110 --> 00:04:34,140
right then the reason why the interior

111
00:04:38,180 --> 00:04:36,120
warms usually in insight planets is

112
00:04:40,850 --> 00:04:38,190
because you have real genic elements

113
00:04:44,780 --> 00:04:40,860

that decay and the decay reaction

114
00:04:46,700 --> 00:04:44,790
produces heat and so this is what heats

115
00:04:48,080 --> 00:04:46,710
up most planets especially these guys

116
00:04:49,820 --> 00:04:48,090
who don't have tidal heating like

117
00:04:53,120 --> 00:04:49,830
europower and Solaris where are the

118
00:04:55,580 --> 00:04:53,130
moons so the center will get hot first

119
00:04:58,100 --> 00:04:55,590
the rock wall separate from ice and this

120
00:04:59,510 --> 00:04:58,110
will proceed outwards so you can get to

121
00:05:01,790 --> 00:04:59,520
intermediate situations like this where

122
00:05:03,740 --> 00:05:01,800
you have a crust of undifferentiated

123
00:05:05,840 --> 00:05:03,750
material that's too frigid to kind of

124
00:05:08,480 --> 00:05:05,850
separate work from ice or you can go all

125
00:05:10,280 --> 00:05:08,490
the way okay so perhaps the progenitor

126
00:05:11,990 --> 00:05:10,290
is going to stop here in this partial

127
00:05:13,850 --> 00:05:12,000
state and then to toe from from from

128
00:05:16,220 --> 00:05:13,860
this stuff and shine from from the crust

129
00:05:18,170 --> 00:05:16,230
and the ice there's one more layer of

130
00:05:20,659 --> 00:05:18,180
complication and it has to do with what

131
00:05:23,000 --> 00:05:20,669
the rock looks like it's pretty hard to

132
00:05:24,080 --> 00:05:23,010
tell what the rock would have been the

133
00:05:26,360 --> 00:05:24,090
de planets formed from but the best

134
00:05:30,230 --> 00:05:26,370
example we have are the most primitive

135
00:05:32,810 --> 00:05:30,240
meteorites that we have in the solar

136
00:05:35,900 --> 00:05:32,820
system least altered and these are

137
00:05:38,810 --> 00:05:35,910
contracts and contracts are made from

138
00:05:40,400 --> 00:05:38,820

these little controls which are little

139
00:05:42,950 --> 00:05:40,410
spheres of about a millimeter in size

140
00:05:45,020 --> 00:05:42,960
and they're suspended in this matrix of

141
00:05:48,170 --> 00:05:45,030
micron sized grains so it's a very

142
00:05:49,670 --> 00:05:48,180
particular grain grain size kind of kind

143
00:05:53,120 --> 00:05:49,680
of solid right so you have big grains

144
00:05:55,760 --> 00:05:53,130
and small grains if you do the math you

145
00:05:58,760 --> 00:05:55,770
find out that it the big rains settle

146
00:05:59,840 --> 00:05:58,770
much faster in water or in ice than the

147
00:06:02,360 --> 00:05:59,850
small grains with it's kind of like

148
00:06:04,760 --> 00:06:02,370
dumping a big block of a big boulder of

149
00:06:06,860 --> 00:06:04,770
rock that will go gree fast but if you

150
00:06:10,219 --> 00:06:06,870
have a little bit of silt it'll take a

151
00:06:12,920 --> 00:06:10,229
long time to settle and doing the math

152
00:06:15,140 --> 00:06:12,930
we find that the controls can settle to

153
00:06:16,430 --> 00:06:15,150
form the core but the matrix can stay

154
00:06:18,980 --> 00:06:16,440
suspended the mixed with the water and

155
00:06:22,040 --> 00:06:18,990
the ice and kind of make maybe a med

156
00:06:24,620 --> 00:06:22,050
ocean or frozen mud and so you can get

157
00:06:28,370 --> 00:06:24,630
in addition to this this axis here you

158
00:06:29,990 --> 00:06:28,380
can get a second axis where you can have

159
00:06:32,390 --> 00:06:30,000
incomplete differentiation because some

160
00:06:34,219 --> 00:06:32,400
of the rocks taste suspended in the ice

161
00:06:36,320 --> 00:06:34,229
and if you have entirely matrix grains

162
00:06:37,640 --> 00:06:36,330
potentially you have never had

163
00:06:40,310 --> 00:06:37,650

differentiation the stuff always

164
00:06:47,180 --> 00:06:40,320
kind of well mix and you can have any

165
00:06:50,060 --> 00:06:47,190
sort of intermediate cases as well all

166
00:06:51,830 --> 00:06:50,070
right so what does that tell us about

167
00:06:53,060 --> 00:06:51,840
the pretenders so the again our goal is

168
00:06:55,969 --> 00:06:53,070
to get a progenitor that that's

169
00:06:58,670 --> 00:06:55,979
partially differentiated so this is a

170
00:07:00,409 --> 00:06:58,680
plot that shows the thermal evolution so

171
00:07:02,810 --> 00:07:00,419
the temperatures inside a progenitor

172
00:07:04,400 --> 00:07:02,820
okay before Pluto and Charon form before

173
00:07:06,350 --> 00:07:04,410
the collision happens so from the

174
00:07:08,210 --> 00:07:06,360
formation until the time of collision

175
00:07:09,350 --> 00:07:08,220
which we assume takes place about a

176
00:07:11,140 --> 00:07:09,360
hundred million years after their

177
00:07:14,120 --> 00:07:11,150
formation it doesn't really matter when

178
00:07:17,029 --> 00:07:14,130
it's about a good indicative time this

179
00:07:20,270 --> 00:07:17,039
is the temperature scale here in Kelvin

180
00:07:21,920 --> 00:07:20,280
and the temperatures go from the center

181
00:07:25,580 --> 00:07:21,930
here to the surface there about a

182
00:07:26,870 --> 00:07:25,590
thousand numbers in size and so what's

183
00:07:28,790 --> 00:07:26,880
happening here is that they form pretty

184
00:07:30,620 --> 00:07:28,800
cold so you're way off to the left of

185
00:07:32,900 --> 00:07:30,630
the scale here and then because of this

186
00:07:34,730 --> 00:07:32,910
radioactive decay they heat up inside

187
00:07:36,800 --> 00:07:34,740
and at some point they reach a

188
00:07:38,719 --> 00:07:36,810

temperature threshold and here the

189
00:07:40,640 --> 00:07:38,729
threshold is the the melting point of a

190
00:07:43,790 --> 00:07:40,650
water ammonia mixture and we assume that

191
00:07:46,040 --> 00:07:43,800
they have water and ammonia and them and

192
00:07:48,529 --> 00:07:46,050
because of melting The Rock starts

193
00:07:51,560 --> 00:07:48,539
falling through the water ammonia ice

194
00:07:53,839 --> 00:07:51,570
and for Mac or we assume some fraction

195
00:07:55,460 --> 00:07:53,849
stays and finds suspended and the

196
00:07:58,279 --> 00:07:55,470
differentiation does take place all the

197
00:08:00,020 --> 00:07:58,289
way there is a crust that remains but

198
00:08:01,580 --> 00:08:00,030
with this particular model and others

199
00:08:04,719 --> 00:08:01,590
it's not very sensitive to different

200
00:08:06,379 --> 00:08:04,729
conditions you you pretty easily get

201
00:08:08,089 --> 00:08:06,389
progenitors that at the time of

202
00:08:10,070 --> 00:08:08,099
collision a partial differentiated so we

203
00:08:13,250 --> 00:08:10,080
can this way reproduce the densities of

204
00:08:15,080 --> 00:08:13,260
Pluto and Charon alright so that was one

205
00:08:17,839 --> 00:08:15,090
ball the second goal is to find out what

206
00:08:19,430 --> 00:08:17,849
happens inside Sharon afterwards during

207
00:08:22,730 --> 00:08:19,440
its history so when the collision

208
00:08:23,930 --> 00:08:22,740
happens everything is kind of reshuffled

209
00:08:25,550 --> 00:08:23,940
right Sharon comes from the outermost

210
00:08:27,200 --> 00:08:25,560
material but during the collision

211
00:08:29,149 --> 00:08:27,210
material gets pulverized and recreated

212
00:08:32,899 --> 00:08:29,159
homogeneously and so we assume Sharon

213
00:08:35,420 --> 00:08:32,909

forms homogeneous again but with a

214
00:08:36,980 --> 00:08:35,430
little less robbed and Pluto and so

215
00:08:42,199 --> 00:08:36,990
again it heats up until different shades

216
00:08:44,600 --> 00:08:42,209
into a core and Meddy mental but now

217
00:08:47,269 --> 00:08:44,610
over time the heat builds up in interior

218
00:08:49,040 --> 00:08:47,279
because the heat from the radioactive

219
00:08:50,850 --> 00:08:49,050
decay doesn't get transported outward

220
00:08:53,400 --> 00:08:50,860
this fast and so

221
00:08:55,380 --> 00:08:53,410
temperatures reach the melting point for

222
00:08:59,280 --> 00:08:55,390
the ice and so you have a notion that

223
00:09:01,319 --> 00:08:59,290
lasts about two billion years and it's

224
00:09:03,000 --> 00:09:01,329
it's quite a large ocean maybe 200

225
00:09:05,400 --> 00:09:03,010
kilometers in thickness in this model

226
00:09:07,380 --> 00:09:05,410
but again the the model is quite robust

227
00:09:11,069 --> 00:09:07,390
here in terms of varying parameters and

228
00:09:13,650 --> 00:09:11,079
so on and then it freezes the reason why

229
00:09:16,350 --> 00:09:13,660
it freezes is that at some point really

230
00:09:18,329 --> 00:09:16,360
DK just can't compete with transport

231
00:09:20,130 --> 00:09:18,339
processes so when you have a notion here

232
00:09:22,139 --> 00:09:20,140
he gets transported by convection

233
00:09:26,040 --> 00:09:22,149
instead of just conduction in the ice

234
00:09:29,930 --> 00:09:26,050
and so Sharon calls a lot faster so

235
00:09:32,160 --> 00:09:29,940
eventually ocean freezes once it freezes

236
00:09:34,949 --> 00:09:32,170
again the heat transfer becomes more

237
00:09:37,110 --> 00:09:34,959
sluggish and so it it healed heat still

238
00:09:39,030 --> 00:09:37,120

builds up a little bit enough to ream

239
00:09:42,300 --> 00:09:39,040
else part of the ocean it's a little

240
00:09:43,769 --> 00:09:42,310
colder and smaller than before but we

241
00:09:45,690 --> 00:09:43,779
have this sort of secondary ocean here

242
00:09:47,370 --> 00:09:45,700
none of this is real or not but the

243
00:09:50,880 --> 00:09:47,380
bottom line is that we can have oceans

244
00:09:54,900 --> 00:09:50,890
for several billion years inside share

245
00:09:56,939 --> 00:09:54,910
and that's that's take away okay so this

246
00:09:59,430 --> 00:09:56,949
is all models do we have any evidence

247
00:10:01,620 --> 00:09:59,440
that this could be the case and

248
00:10:03,329 --> 00:10:01,630
unfortunately I knew this was gonna

249
00:10:08,400 --> 00:10:03,339
happen because i had the keynote and i

250
00:10:10,980 --> 00:10:08,410
forgot to okay put away the animations

251
00:10:14,160 --> 00:10:10,990
okay let me show you this so i'm sharon

252
00:10:16,350 --> 00:10:14,170
remembered is this canyon here at the

253
00:10:19,110 --> 00:10:16,360
surface that that's was shown in the

254
00:10:21,060 --> 00:10:19,120
format talk and to me this Canyon is

255
00:10:23,960 --> 00:10:21,070
reminiscence of a baguette as a

256
00:10:27,030 --> 00:10:23,970
Frenchman I always think of a bread

257
00:10:28,920 --> 00:10:27,040
but but the analogy is actually quite

258
00:10:33,090 --> 00:10:28,930
good good because you get this when the

259
00:10:35,130 --> 00:10:33,100
baguette Rises or swells when you bake

260
00:10:36,960 --> 00:10:35,140
it right and so on Sharon you get this

261
00:10:39,450 --> 00:10:36,970
little Canyon here because it looks like

262
00:10:41,730 --> 00:10:39,460
it expanded upon freezing right eye

263
00:10:43,290 --> 00:10:41,740

steaks more space than water and so if

264
00:10:45,270 --> 00:10:43,300
you freezing ocean would expect Sharon

265
00:10:48,660 --> 00:10:45,280
to kind of increase in size from

266
00:10:50,730 --> 00:10:48,670
freezing and so perhaps this giant

267
00:10:55,470 --> 00:10:50,740
system of Kenyan belts at Sharon's

268
00:10:56,580 --> 00:10:55,480
equator is a sign that university you

269
00:10:58,920 --> 00:10:56,590
would have form upon freezing at the

270
00:11:00,570 --> 00:10:58,930
ocean we can talk about dates later I've

271
00:11:02,250 --> 00:11:00,580
Ryan mentioned that most of the surface

272
00:11:04,410 --> 00:11:02,260
looks older than four billion years so

273
00:11:06,930 --> 00:11:04,420
that we put it here and I'm saying it

274
00:11:08,040 --> 00:11:06,940
happens here at two billion years so

275
00:11:14,480 --> 00:11:08,050
there is an issue that needs to be

276
00:11:17,970 --> 00:11:16,650
ok and then then the second interesting

277
00:11:19,830 --> 00:11:17,980
thing you can kind of see her on the

278
00:11:21,510 --> 00:11:19,840
limb and accuse them and it looks like

279
00:11:23,340 --> 00:11:21,520
this there is this very interesting

280
00:11:24,690 --> 00:11:23,350
mountain in the modes that you guess I

281
00:11:27,750 --> 00:11:24,700
might have heard from the press release

282
00:11:28,830 --> 00:11:27,760
from the new horizons team and this has

283
00:11:30,990 --> 00:11:28,840
been the puzzle we don't see this

284
00:11:34,170 --> 00:11:31,000
anywhere else in the solar system or

285
00:11:36,510 --> 00:11:34,180
maybe almost nowhere else the closest

286
00:11:38,540 --> 00:11:36,520
analogue that my advisor Steve and I

287
00:11:40,800 --> 00:11:38,550
could think of is the Hawaiian Islands

288
00:11:43,410 --> 00:11:40,810

you can see here this little depression

289
00:11:45,420 --> 00:11:43,420
little deeper here around the island and

290
00:11:48,390 --> 00:11:45,430
the reason why that is is because when

291
00:11:50,580 --> 00:11:48,400
you have volcanism so the you know new

292
00:11:52,590 --> 00:11:50,590
rockets gets gets formed then there's a

293
00:11:55,890 --> 00:11:52,600
whole volcano here and it kind of ways

294
00:11:58,050 --> 00:11:55,900
on the crust and kind of flexes it down

295
00:12:00,960 --> 00:11:58,060
and so you can see the the flexure here

296
00:12:03,590 --> 00:12:00,970
so it kind of looks like this so could

297
00:12:07,230 --> 00:12:03,600
this could this be happening on Sharon

298
00:12:09,300 --> 00:12:07,240
again if you do the math you can find

299
00:12:12,090 --> 00:12:09,310
the minimum or did I guess the maximum

300
00:12:14,040 --> 00:12:12,100
thickness of the crest here so that

301
00:12:15,960 --> 00:12:14,050
it'll flex you know if it's paper thin

302
00:12:17,250 --> 00:12:15,970
of course it'll flex but if it's a

303
00:12:20,370 --> 00:12:17,260
hundred kilometres thick maybe it won't

304
00:12:21,930 --> 00:12:20,380
right and so you find out that if it's

305
00:12:24,630 --> 00:12:21,940
above a few kilometers it's really hard

306
00:12:27,510 --> 00:12:24,640
to flex it this way and the only way you

307
00:12:30,000 --> 00:12:27,520
can get something you know solid or not

308
00:12:31,350 --> 00:12:30,010
viscous for a few kilometers is that you

309
00:12:33,870 --> 00:12:31,360
need to have a lot of heat coming under

310
00:12:35,580 --> 00:12:33,880
it because the surface is so cold here

311
00:12:38,360 --> 00:12:35,590
and the only way to get so much heat is

312
00:12:42,990 --> 00:12:38,370
to have some sort of cryo magma chamber

313
00:12:45,360 --> 00:12:43,000

so some sort of you know viscous ice or

314
00:12:47,310 --> 00:12:45,370
maybe liquid right under the surface

315
00:12:49,260 --> 00:12:47,320
that maybe erupts a little bit of

316
00:12:50,970 --> 00:12:49,270
material and flexes the crust or it just

317
00:12:52,980 --> 00:12:50,980
kind of comes under the crust and then

318
00:12:55,890 --> 00:12:52,990
it collapses over it in this sort of bit

319
00:12:57,930 --> 00:12:55,900
here so again I'm not saying this is

320
00:12:59,400 --> 00:12:57,940
happening today or that this has

321
00:13:02,400 --> 00:12:59,410
happened all over the history of Sharon

322
00:13:06,600 --> 00:13:02,410
but perhaps you know when the last bit

323
00:13:08,130 --> 00:13:06,610
of the ocean froze the the in interior

324
00:13:09,450 --> 00:13:08,140
the ice can it took more space than

325
00:13:12,150 --> 00:13:09,460
water and kind of squeeze whatever

326
00:13:13,230 --> 00:13:12,160
pockets of water were left up to the

327
00:13:14,760 --> 00:13:13,240
surface so Brad you were asking a

328
00:13:16,890 --> 00:13:14,770
question about this there how can you

329
00:13:18,390 --> 00:13:16,900
get this by squeezing water it's kind of

330
00:13:20,130 --> 00:13:18,400
a witch of shooting it up to the surface

331
00:13:24,060 --> 00:13:20,140
and kind of overcoming the negative

332
00:13:26,490 --> 00:13:24,070
buoyancy of liquid water in the ice so

333
00:13:28,620 --> 00:13:26,500
anyway just just to sum up so Sharon

334
00:13:31,320 --> 00:13:28,630
Pluto likely form when to partially

335
00:13:33,480 --> 00:13:31,330
differentiated progenitor is collided

336
00:13:34,980 --> 00:13:33,490
and we can reproduce the structure that

337
00:13:38,280 --> 00:13:34,990
matches the densities of Pluto and

338
00:13:39,690 --> 00:13:38,290

Charon the thermal mulling strongly

339
00:13:41,280 --> 00:13:39,700
suggest that churn had an ocean for a

340
00:13:44,250 --> 00:13:41,290
long time another until today but for

341
00:13:45,900 --> 00:13:44,260
civil billions of years so you know diff

342
00:13:47,550 --> 00:13:45,910
other solar systems are younger than

343
00:13:50,940 --> 00:13:47,560
ours and it's very possible that there

344
00:13:53,550 --> 00:13:50,950
are oceans in many places elsewhere even

345
00:13:55,320 --> 00:13:53,560
though now i'm sharing today and it

346
00:13:58,020 --> 00:13:55,330
looks like ocean freezing shape the

347
00:14:04,780 --> 00:13:58,030
surface so that sharon actually had an

348
00:14:16,670 --> 00:14:14,480
questions remark hey good talk mark I've

349
00:14:19,400 --> 00:14:16,680
set a question I'm not really a

350
00:14:22,310 --> 00:14:19,410
geologist but for like the Hawaiian

351
00:14:24,050 --> 00:14:22,320
island analogy those are thought to be

352
00:14:26,380 --> 00:14:24,060
formed by like mantle plumes which are

353
00:14:30,620 --> 00:14:26,390
different from like getting a volcano

354
00:14:32,810 --> 00:14:30,630
forming from a magma chamber so I don't

355
00:14:35,930 --> 00:14:32,820
know is it just is it just a issue of

356
00:14:39,980 --> 00:14:35,940
the size scale of the feature itself

357
00:14:42,620 --> 00:14:39,990
yeah I would say so so you know you when

358
00:14:43,880 --> 00:14:42,630
you talk about mental plumes versus you

359
00:14:45,680 --> 00:14:43,890
know volcanoes are rising from the

360
00:14:46,850 --> 00:14:45,690
tectonic processes and and so on someone

361
00:14:49,880 --> 00:14:46,860
who's more of a geologist then we can

362
00:14:51,590 --> 00:14:49,890
correct me if I'm wrong but essentially

363
00:14:53,720 --> 00:14:51,600

it's just telling you that the magma has

364
00:14:55,310 --> 00:14:53,730
a deep source and kind of very local

365
00:14:59,389 --> 00:14:55,320
source so that that's the case for the

366
00:15:00,920 --> 00:14:59,399
Hawaiian Islands the the magma chamber

367
00:15:02,120 --> 00:15:00,930
here you're talking about a very small

368
00:15:04,910 --> 00:15:02,130
scale thing compared to the scale of the

369
00:15:07,009 --> 00:15:04,920
plumes or the plumes would be and who

370
00:15:08,660 --> 00:15:07,019
knows if there are plumes but the source

371
00:15:10,850 --> 00:15:08,670
of the magma is hundreds of maybe

372
00:15:12,350 --> 00:15:10,860
thousands of kilometers deep but the

373
00:15:13,910 --> 00:15:12,360
magma chamber here you're talking just a

374
00:15:16,100 --> 00:15:13,920
few kilometers right so it's just a

375
00:15:17,990 --> 00:15:16,110
little blip around the plume and maybe

376
00:15:20,689 --> 00:15:18,000
the the ascent is kind of stalled

377
00:15:24,980 --> 00:15:20,699
because again the water is supposed to

378
00:15:28,040 --> 00:15:24,990
sink in ice so you know it's competition

379
00:15:29,569 --> 00:15:28,050
between the squeezing forces that and

380
00:15:31,189 --> 00:15:29,579
the pressurization that makes the fluid

381
00:15:32,930 --> 00:15:31,199
go up and the gravity that makes it go

382
00:15:34,550 --> 00:15:32,940
down and so at some point you might

383
00:15:35,960 --> 00:15:34,560
reach some zone of neutral buoyancy

384
00:15:37,310 --> 00:15:35,970
where he had a little bit of

385
00:15:38,889 --> 00:15:37,320
accumulation I think that's what happens

386
00:15:43,819 --> 00:15:38,899
in their terrestrial volcanoes as well

387
00:15:48,439 --> 00:15:43,829
so yeah it's not incompatible yeah yes

388
00:15:51,350 --> 00:15:48,449

um so how is the surface age determined

389
00:15:52,790 --> 00:15:51,360
because you know generally I think about

390
00:15:55,370 --> 00:15:52,800
surface ages being determined in terms

391
00:15:57,970 --> 00:15:55,380
of crater counting but that surface to

392
00:16:00,110 --> 00:15:57,980
me does not look saturated with craters

393
00:16:02,090 --> 00:16:00,120
so I was just wondering how they

394
00:16:04,329 --> 00:16:02,100
determine the surface age yeah this is

395
00:16:08,900 --> 00:16:04,339
an excellent question and again people

396
00:16:11,120 --> 00:16:08,910
more aware than you can can answer so

397
00:16:13,610 --> 00:16:11,130
the in the Kuiper belt it's it's pretty

398
00:16:15,769 --> 00:16:13,620
hard right the the absolute dating we

399
00:16:16,590 --> 00:16:15,779
get usually from critter counting comes

400
00:16:20,009 --> 00:16:16,600
from the your

401
00:16:22,019 --> 00:16:20,019
the moon so you know you can date

402
00:16:23,759 --> 00:16:22,029
originally some rocks from the moon you

403
00:16:26,160 --> 00:16:23,769
know how many craters are on them and so

404
00:16:27,480 --> 00:16:26,170
you have some sort of a scale it's it's

405
00:16:28,949 --> 00:16:27,490
actually really hard to extrapolate the

406
00:16:30,569 --> 00:16:28,959
scale elsewhere in the solar system and

407
00:16:32,040 --> 00:16:30,579
particularly in the Kuiper belt where

408
00:16:35,790 --> 00:16:32,050
the collisional history must have been

409
00:16:38,999 --> 00:16:35,800
so different so the the way it's been

410
00:16:41,550 --> 00:16:39,009
done it's kind of 22 with models of how

411
00:16:43,769 --> 00:16:41,560
the caravel population changed over time

412
00:16:45,360 --> 00:16:43,779
through collisions and so on and it's

413
00:16:49,319 --> 00:16:45,370

informed by the size distribution of

414
00:16:51,090 --> 00:16:49,329
care belt objects currently as they are

415
00:16:52,949 --> 00:16:51,100
observed so I'm kind of on the on the

416
00:16:55,829 --> 00:16:52,959
big end of it the ones that you can see

417
00:16:56,910 --> 00:16:55,839
and on the small end of it mostly it's

418
00:16:58,230 --> 00:16:56,920
built from what we're seeing on Twitter

419
00:16:59,910 --> 00:16:58,240
and Sharon said kinda it's kind of like

420
00:17:01,470 --> 00:16:59,920
a snake bites its tail right you can

421
00:17:05,669 --> 00:17:01,480
date widow and sure and based on what

422
00:17:08,100 --> 00:17:05,679
you see on them so and they've been

423
00:17:10,340 --> 00:17:08,110
competing models currently the the new

424
00:17:14,010 --> 00:17:10,350
horizons team has strongly converged on

425
00:17:16,490 --> 00:17:14,020
a single model that seems very plausible

426
00:17:18,480 --> 00:17:16,500
and according to this model to the

427
00:17:21,210 --> 00:17:18,490
service efficient is really old even

428
00:17:23,250 --> 00:17:21,220
though it's spiracy created just because

429
00:17:26,309 --> 00:17:23,260
it hasn't impacted that much there

430
00:17:28,260 --> 00:17:26,319
weren't that many impactors so that you

431
00:17:29,970 --> 00:17:28,270
know that's one model that everyone's

432
00:17:32,490 --> 00:17:29,980
agreeing on but who knows right it's

433
00:17:34,289 --> 00:17:32,500
it's all model dependent our results of

434
00:17:36,630 --> 00:17:34,299
a late ocean saying that the surface is

435
00:17:38,549 --> 00:17:36,640
maybe perhaps you know or at least the

436
00:17:40,710 --> 00:17:38,559
planes are two billion years old still

437
00:17:45,810 --> 00:17:40,720
for is also model dependent so it's kind

438
00:17:47,640 --> 00:17:45,820

of reaching your agreement there yeah so

439
00:17:51,930 --> 00:17:47,650
assuming New Horizons data four billion

440
00:17:54,830 --> 00:17:51,940
years is correct um I mean it is what

441
00:17:58,260 --> 00:17:54,840
you've what you found is that contradict

442
00:18:00,299 --> 00:17:58,270
new horizons I mean the if there's an

443
00:18:01,950 --> 00:18:00,309
ocean underneath for two billion till

444
00:18:04,590 --> 00:18:01,960
two billion years ago yeah doesn't

445
00:18:08,970 --> 00:18:04,600
necessarily have to show itself through

446
00:18:11,940 --> 00:18:08,980
surface features not necessarily you can

447
00:18:14,700 --> 00:18:11,950
kind of compute how much Sharon should

448
00:18:16,620 --> 00:18:14,710
have swollen you know based on how much

449
00:18:18,840 --> 00:18:16,630
ocean there was so there was an ocean

450
00:18:20,730 --> 00:18:18,850
200 kilometers deep and the density of

451
00:18:22,950 --> 00:18:20,740
water is blonde at the city of Isis

452
00:18:25,169 --> 00:18:22,960
blood and Sharon should inflate by block

453
00:18:26,399 --> 00:18:25,179
and essentially you can kind of account

454
00:18:28,110 --> 00:18:26,409
for the whole extension through the

455
00:18:29,400 --> 00:18:28,120
canyons for example but the canyons

456
00:18:32,560 --> 00:18:29,410
themselves look

457
00:18:34,480 --> 00:18:32,570
there were four billion years old so in

458
00:18:36,280 --> 00:18:34,490
this sense you know it's contrary but

459
00:18:37,660 --> 00:18:36,290
perhaps the canyons are due to something

460
00:18:40,500 --> 00:18:37,670
else and they could have in a notion