Panelists


Attendees (12)

- Hosts (1)
  - Mike Toillion
- Presenters (3)
  - Andy Burnett
  - Jamie Elsila Cook
  - mjmumma
- Participants (8)
  - Doug Whittet
  - Fred Ciesla
  - Gal Sarid (Harvard)
  - K Meech
  - Murthy Gudipati
  - Pauli Laine
  - Penny Boston
  - ron oremland

Open Chat (Everyone)

**GSFC:** Waiting for system to warm up

**Mike Toillion:** No worries, let me know if I can help with anything.

**Mike Toillion:** Hi Doug : )

--------- (01/22/2014 10:57) ---------

**Doug Whittet:** Hi!

--------- (01/22/2014 10:59) ---------

**Murthy Gudipati:** Hello! Is the sound off (I can't hear)?

**Mike Toillion:** For audio, please dial into the teleconference below.

**Murthy Gudipati:** OK - let's hope we will have a good sync!

--------- (01/22/2014 11:03) ---------

**Murthy Gudipati:** *6 to UNMUTE as well?

**Mike Toillion:** Yes, that's correct. Thanks!

--------- (01/22/2014 11:09) ---------

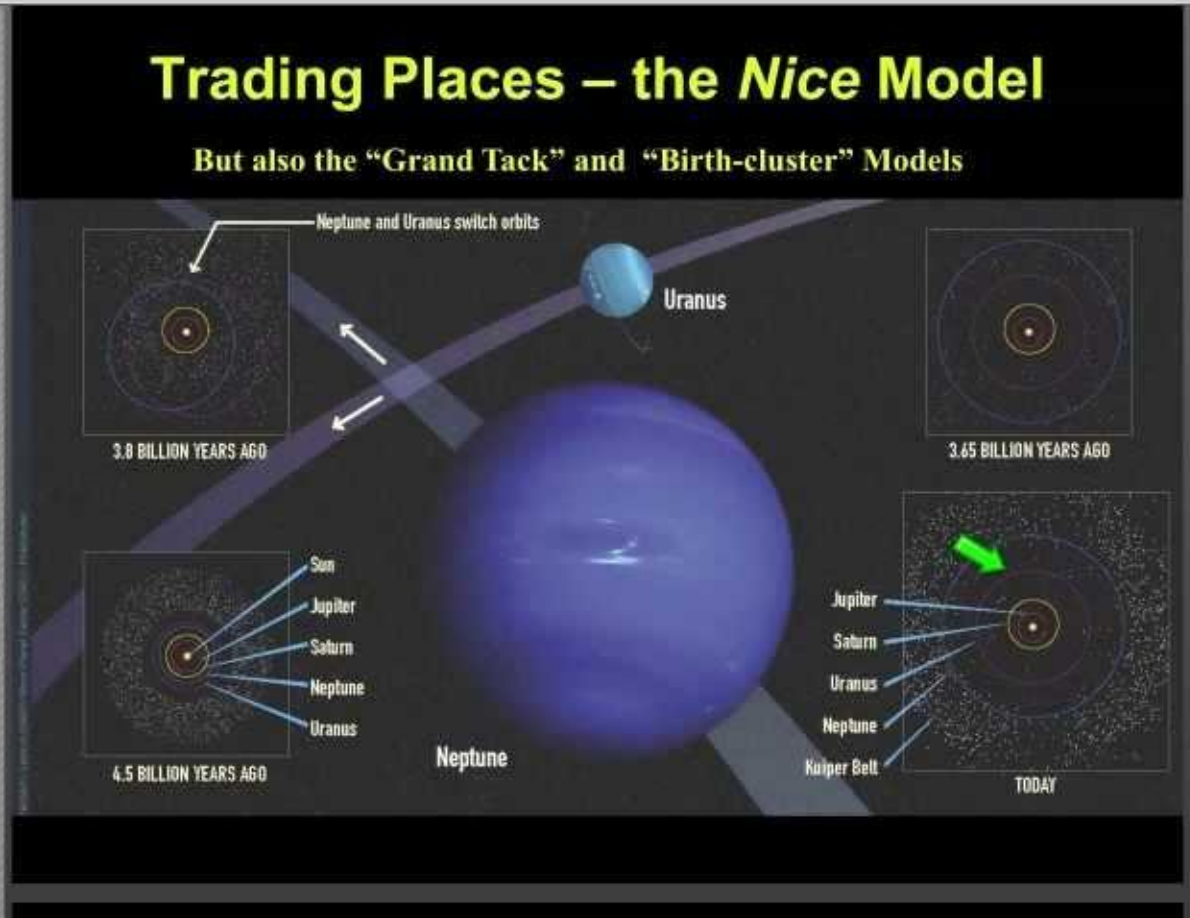
**Mike Toillion:** To expand the slides locally, click the Full Screen button located to the upper right of the slides.

Audio Instructions (Participants)

**Teleconference Line: 866-692-3158**
**Passcode: 9109668#**
Please use *6 (STAR, then 6) to MUTE your phone's mic when not speaking.
*More info: https://astrobiologyfuture.org*

What Roles do Primitive Icy Bodies Play in the Origin of Life?

Full Screen



1
00:00:13,520 --> 00:00:11,450
just very very briefly i'm going to say

2
00:00:15,470 --> 00:00:13,530
good afternoon to the people watching

3
00:00:18,500 --> 00:00:15,480
and also to anyone who's going to be

4
00:00:21,349 --> 00:00:18,510
watching this are as a recording just a

5
00:00:23,870 --> 00:00:21,359
few aunt min notes to deal with if you

6
00:00:26,210 --> 00:00:23,880
happen to be dialed into this but only

7
00:00:29,900 --> 00:00:26,220
on the audio side you are welcome to

8
00:00:32,900 --> 00:00:29,910
download the slides which are loop 2 in

9
00:00:35,500 --> 00:00:32,910
the event for today on the front of the

10
00:00:37,819 --> 00:00:35,510
website if you've been looking a

11
00:00:41,299 --> 00:00:37,829
document that's the basis of this

12
00:00:43,160 --> 00:00:41,309
presentation in the last day or so it

13
00:00:46,190 --> 00:00:43,170

changed quite significantly and I just

14
00:00:48,560 --> 00:00:46,200
wanted to mention the fact that it was

15
00:00:51,500 --> 00:00:48,570
being edited in a different system we

16
00:00:54,740 --> 00:00:51,510
then uploaded the revised document into

17
00:00:56,959 --> 00:00:54,750
Google Docs the comments that have been

18
00:00:58,970 --> 00:00:56,969
added entered previously therefore

19
00:01:01,580 --> 00:00:58,980
vanished but I wouldn't want anyone to

20
00:01:04,340 --> 00:01:01,590
think that they weren't read it was just

21
00:01:07,070 --> 00:01:04,350
part of the editing cycle the title was

22
00:01:09,140 --> 00:01:07,080
also a new and improved one just in case

23
00:01:11,960 --> 00:01:09,150
anyone was thinking wait is this the one

24
00:01:14,300 --> 00:01:11,970
that I'm is meant to the end and finally

25
00:01:17,179 --> 00:01:14,310
this session is being recorded so

26
00:01:20,240 --> 00:01:17,189
anything that you type or say is going

27
00:01:21,890 --> 00:01:20,250
to be placed on the internet and with

28
00:01:27,920 --> 00:01:21,900
that I think I'm going to pass over to

29
00:01:29,840 --> 00:01:27,930
Mike okay welcome everyone Jamie and I

30
00:01:33,050 --> 00:01:29,850
are going to teen tag on this

31
00:01:36,710 --> 00:01:33,060
presentation and as you some of you

32
00:01:39,550 --> 00:01:36,720
probably know see earlier led a webinar

33
00:01:41,660 --> 00:01:39,560
on the organics that are found in

34
00:01:43,819 --> 00:01:41,670
primitive meteorites particularly

35
00:01:47,749 --> 00:01:43,829
carbonaceous chondrites and also in

36
00:01:50,060 --> 00:01:47,759
commentary samples so for that reason we

37
00:01:54,440 --> 00:01:50,070
didn't delete the word I see from the

38
00:01:57,910 --> 00:01:54,450

title new title but we do really want to

39
00:02:01,179 --> 00:01:57,920
address the issue of where are the major

40
00:02:04,190 --> 00:02:01,189
issues and what do we know about

41
00:02:06,830 --> 00:02:04,200
primitive bodies in the solar system and

42
00:02:07,350 --> 00:02:06,840
their role in delivering organics and

43
00:02:09,779 --> 00:02:07,360
water

44
00:02:13,620 --> 00:02:09,789
to especially the young earth but also

45
00:02:17,300 --> 00:02:13,630
to the other planets such as Mars so

46
00:02:20,390 --> 00:02:17,310
with that we have prepared a number of

47
00:02:23,280 --> 00:02:20,400
graphics here to give you a little more

48
00:02:26,730 --> 00:02:23,290
visual information on things that are

49
00:02:29,310 --> 00:02:26,740
written down in words but probably will

50
00:02:31,230 --> 00:02:29,320
jump over a few of these graphics rather

51
00:02:34,910 --> 00:02:31,240
than discuss it in detail that you will

52
00:02:37,830 --> 00:02:34,920
be able to access those at your will

53
00:02:40,650 --> 00:02:37,840
when your download the presentation and

54
00:02:44,810 --> 00:02:40,660
of course we would invite anyone to

55
00:02:47,130 --> 00:02:44,820
interrupt the remarks at any time

56
00:02:50,220 --> 00:02:47,140
because the whole point here is to gain

57
00:02:52,050 --> 00:02:50,230
new insights from you and also to

58
00:02:55,890 --> 00:02:52,060
discuss the insights that the team is

59
00:03:00,150 --> 00:02:55,900
developed so this particular document

60
00:03:03,150 --> 00:03:00,160
which is on the web now was developed by

61
00:03:06,900 --> 00:03:03,160
the folks whose names you see here any

62
00:03:11,850 --> 00:03:06,910
Fred Paulie Francis dark myself and

63
00:03:13,890 --> 00:03:11,860

Jamie and so the final editing of the

64
00:03:17,460 --> 00:03:13,900
presentation was done by Jamie and

65
00:03:19,830 --> 00:03:17,470
myself as recently as this morning so we

66
00:03:21,979 --> 00:03:19,840
take the full blame and give the credit

67
00:03:26,670 --> 00:03:21,989
to others for what you're about to hear

68
00:03:30,479 --> 00:03:26,680
all right so let's move on now the issue

69
00:03:33,360 --> 00:03:30,489
is what can we say about the S or

70
00:03:35,039 --> 00:03:33,370
biological significance of comets what

71
00:03:37,560 --> 00:03:35,049
was that what was their role and by the

72
00:03:39,600 --> 00:03:37,570
way of course to be rights as well what

73
00:03:42,900 --> 00:03:39,610
was the role in delivering water and

74
00:03:45,660 --> 00:03:42,910
prebiotic organics to early Earth as

75
00:03:48,060 --> 00:03:45,670
you'll see in this outline we're going

76
00:03:52,949 --> 00:03:48,070
to present this morning this afternoon

77
00:03:57,090 --> 00:03:52,959
rather depends where you are the issue

78
00:03:58,500 --> 00:03:57,100
is not so simply resolved because within

79
00:04:01,470 --> 00:03:58,510
the last 10 years there's been a

80
00:04:05,460 --> 00:04:01,480
tremendous revolution that has occurred

81
00:04:07,740 --> 00:04:05,470
in our understanding of the motion of

82
00:04:10,560 --> 00:04:07,750
planets early in the solar system and

83
00:04:12,880 --> 00:04:10,570
the way which that not only mixed the

84
00:04:17,170 --> 00:04:12,890
populations of dry and

85
00:04:19,420 --> 00:04:17,180
icy bodies radially but also then change

86
00:04:22,330 --> 00:04:19,430
the understanding of what was delivered

87
00:04:24,580 --> 00:04:22,340
to terrestrial planets and when that

88
00:04:28,120 --> 00:04:24,590

delivery occurred it's still an evolving

89
00:04:30,310 --> 00:04:28,130
picture so the other part of the problem

90
00:04:34,540 --> 00:04:30,320
is that we really don't have very good

91
00:04:38,950 --> 00:04:34,550
information yet on the taxonomy of these

92
00:04:41,470 --> 00:04:38,960
icy planetesimals because it's only been

93
00:04:44,670 --> 00:04:41,480
the past 20 years that we've really had

94
00:04:46,860 --> 00:04:44,680
the powerful infrared and radio

95
00:04:50,080 --> 00:04:46,870
instruments that can permit us to

96
00:04:53,890 --> 00:04:50,090
quantify the actual organic composition

97
00:04:57,760 --> 00:04:53,900
and water in these various bodies we'll

98
00:05:02,290 --> 00:04:57,770
talk about that for a bit so let's go on

99
00:05:03,880 --> 00:05:02,300
then and begin with the story you have

100
00:05:09,159 --> 00:05:03,890
to remember to use that little arrow

101
00:05:11,920 --> 00:05:09,169
there this chart shows a cartoon of some

102
00:05:14,530 --> 00:05:11,930
of the processes that occurred in the

103
00:05:17,290 --> 00:05:14,540
planet-forming phase actually from the

104
00:05:19,630 --> 00:05:17,300
running running from the collapse of the

105
00:05:23,620 --> 00:05:19,640
natal cloud core and the formation of

106
00:05:26,320 --> 00:05:23,630
the proto solar nebula and then evolving

107
00:05:29,440 --> 00:05:26,330
towards the protoplanetary disk and in

108
00:05:33,010 --> 00:05:29,450
particular there many processes that we

109
00:05:36,700 --> 00:05:33,020
now know occurred at that time some of

110
00:05:39,850 --> 00:05:36,710
them like in is a pointer for a moment

111
00:05:44,230 --> 00:05:39,860
some of them actually involve transport

112
00:05:46,690 --> 00:05:44,240
both radially in and out some involved

113
00:05:50,590 --> 00:05:46,700

transport vertically shown over here is

114
00:05:52,420 --> 00:05:50,600
a circle above the midplane a carrying

115
00:05:55,180 --> 00:05:52,430
material up to the region where UV

116
00:05:57,330 --> 00:05:55,190
optical and x-rays can penetrate and of

117
00:06:00,700 --> 00:05:57,340
course that represents different depths

118
00:06:02,770 --> 00:06:00,710
but there one can actually see a lot of

119
00:06:05,320 --> 00:06:02,780
processing going on in these ways a lot

120
00:06:07,150 --> 00:06:05,330
of laboratory astro chemistry and

121
00:06:10,510 --> 00:06:07,160
chemical physics is going on to

122
00:06:14,290 --> 00:06:10,520
understand these processes but as you

123
00:06:16,540 --> 00:06:14,300
can imagine the taking these kinds of

124
00:06:17,780 --> 00:06:16,550
processes and relating those to what we

125
00:06:20,510 --> 00:06:17,790
now see and kana

126
00:06:22,610 --> 00:06:20,520
and primitive meteorites is a major

127
00:06:24,530 --> 00:06:22,620
story in itself and one that's

128
00:06:28,250 --> 00:06:24,540
developing and will continue to develop

129
00:06:31,300 --> 00:06:28,260
for the next few decades I believe so so

130
00:06:37,280 --> 00:06:31,310
that's part of the picture as well

131
00:06:40,030 --> 00:06:37,290
jumping from the the nebular page to the

132
00:06:43,790 --> 00:06:40,040
point at which the Sun formed about 4.6

133
00:06:45,620 --> 00:06:43,800
billion years ago one of the

134
00:06:48,620 --> 00:06:45,630
developments that occurred just in the

135
00:06:53,480 --> 00:06:48,630
last three years was the development of

136
00:06:57,760 --> 00:06:53,490
a model to describe the migration of

137
00:07:02,180 --> 00:06:57,770
giant planets from the their punitive

138
00:07:05,060 --> 00:07:02,190

formative zones inward towards 1.5 au

139
00:07:08,840 --> 00:07:05,070
and outward again to their current

140
00:07:10,940 --> 00:07:08,850
resident locations the sack actually

141
00:07:16,490 --> 00:07:10,950
occurred within the first hundred

142
00:07:19,730 --> 00:07:16,500
thousand years or so and the dynamical

143
00:07:22,700 --> 00:07:19,740
simulations actually go on until 600k

144
00:07:27,470 --> 00:07:22,710
years but the key point is that Jupiter

145
00:07:29,720 --> 00:07:27,480
and Saturn migrated inward as a result

146
00:07:31,940 --> 00:07:29,730
of gas drag this is all before the gas

147
00:07:33,830 --> 00:07:31,950
cleared the nebula you'll notice it's

148
00:07:36,740 --> 00:07:33,840
long before the formation of the

149
00:07:39,290 --> 00:07:36,750
terrestrial planets and it's long before

150
00:07:41,570 --> 00:07:39,300
the of course the mood forming event

151
00:07:44,210 --> 00:07:41,580
which was roughly 40 to 80 million years

152
00:07:47,090 --> 00:07:44,220
after formation of the earth on

153
00:07:48,860 --> 00:07:47,100
formation of the Sun excuse me the key

154
00:07:52,330 --> 00:07:48,870
point and take home point of this slide

155
00:07:58,640 --> 00:07:52,340
is that if you look at the center panel

156
00:08:00,650 --> 00:07:58,650
the particular card bars are the color

157
00:08:05,120 --> 00:08:00,660
points represent material that was

158
00:08:07,070 --> 00:08:05,130
formed either within about two au of the

159
00:08:10,060 --> 00:08:07,080
Sun or outbound of that so these would

160
00:08:13,120 --> 00:08:10,070
be dry planetesimals

161
00:08:15,160 --> 00:08:13,130
in the former case and I see ones or wet

162
00:08:17,800 --> 00:08:15,170
ones if you like that were formed

163
00:08:22,480 --> 00:08:17,810

farther out this process when Jupiter

164
00:08:25,570 --> 00:08:22,490
actually migrated inwards and then out

165
00:08:28,750 --> 00:08:25,580
again left the this material in the

166
00:08:34,060 --> 00:08:28,760
region of the scattered around in the

167
00:08:37,690 --> 00:08:34,070
region of one to three at you and so it

168
00:08:41,469 --> 00:08:37,700
mixed the dry planetesimals outwards and

169
00:08:43,120 --> 00:08:41,479
the icy winds inward of course the icy

170
00:08:46,510 --> 00:08:43,130
ones would have vaporized or begun to

171
00:08:50,140 --> 00:08:46,520
sublime but if one extends that beyond

172
00:08:52,390 --> 00:08:50,150
this to what happened that as far out of

173
00:08:55,990 --> 00:08:52,400
six and eight a you what it means is

174
00:08:58,900 --> 00:08:56,000
that material that was was mixed and

175
00:09:00,460 --> 00:08:58,910
from one region into another and so this

176
00:09:02,650 --> 00:09:00,470
will play a major role in understanding

177
00:09:06,880 --> 00:09:02,660
what was delivered to the growing

178
00:09:09,910 --> 00:09:06,890
proto-earth proto mars and so on but

179
00:09:13,570 --> 00:09:09,920
also in what role later developments had

180
00:09:15,190 --> 00:09:13,580
toward subsequently delivery material to

181
00:09:17,410 --> 00:09:15,200
the altar estrella planets and of course

182
00:09:20,020 --> 00:09:17,420
we need to know the nature of these

183
00:09:24,280 --> 00:09:20,030
bodies in order to assess what it was

184
00:09:26,680 --> 00:09:24,290
that could have delivered ok so the

185
00:09:29,170 --> 00:09:26,690
grant sack is this is called actually

186
00:09:32,020 --> 00:09:29,180
succeeds in predicting a low-mass mars

187
00:09:34,540 --> 00:09:32,030
and most other models do not succeed at

188
00:09:37,480 --> 00:09:34,550

that so this has given it more than just

189
00:09:40,870 --> 00:09:37,490
casual acceptance within the community

190
00:09:44,670 --> 00:09:40,880
we don't know that it's fully correct so

191
00:09:49,900 --> 00:09:44,680
on these are course developing things so

192
00:09:54,580 --> 00:09:49,910
let's move on a bit after formation of

193
00:09:56,650 --> 00:09:54,590
the planetary system let's call that to

194
00:09:59,740 --> 00:09:56,660
be at around 100 million years at

195
00:10:02,220 --> 00:09:59,750
formation of the Sun a separate

196
00:10:05,080 --> 00:10:02,230
dynamical model called the nice model

197
00:10:08,500 --> 00:10:05,090
actually predicts the dynamical

198
00:10:10,720 --> 00:10:08,510
evolution of the outer planet region and

199
00:10:13,060 --> 00:10:10,730
roots begins at 100 million years with

200
00:10:15,430 --> 00:10:13,070
the outer planets now and they're

201
00:10:18,510 --> 00:10:15,440
approximately their their current

202
00:10:20,820 --> 00:10:18,520
locations between 5 and 14 astronaut

203
00:10:23,220 --> 00:10:20,830
good units and they were in the order of

204
00:10:26,550 --> 00:10:23,230
Jupiter Saturn Neptune and then Uranus

205
00:10:29,580 --> 00:10:26,560
Neptune wind-up tune inside because you

206
00:10:32,100 --> 00:10:29,590
need to make neptr Oh Neptune in within

207
00:10:33,720 --> 00:10:32,110
that hundred million year interval and

208
00:10:36,930 --> 00:10:33,730
it's difficult to do it if it's very far

209
00:10:39,630 --> 00:10:36,940
away but even Uranus was only 14 AU from

210
00:10:43,160 --> 00:10:39,640
the protosun from the Sun at that time

211
00:10:45,870 --> 00:10:43,170
there also was an icy disk planetesimals

212
00:10:48,300 --> 00:10:45,880
and of course as we now know from the

213
00:10:49,860 --> 00:10:48,310

previous slide this disk probably also

214
00:10:52,980 --> 00:10:49,870
contains some material that have been

215
00:10:55,530 --> 00:10:52,990
injected outward from the dry region of

216
00:11:00,480 --> 00:10:55,540
the protoplanetary disk 2 1 2 3 au

217
00:11:03,500 --> 00:11:00,490
region then as Jupiter Saturn migrated

218
00:11:06,960 --> 00:11:03,510
to their tutor one knee motion residents

219
00:11:11,700 --> 00:11:06,970
by ejection of planetesimals and they're

220
00:11:14,280 --> 00:11:11,710
feeding zones they basically caused a

221
00:11:18,420 --> 00:11:14,290
destabilization of the disk at around

222
00:11:21,690 --> 00:11:18,430
3.8 billion years ago in which Neptune

223
00:11:24,750 --> 00:11:21,700
and Uranus now switch places and the

224
00:11:28,170 --> 00:11:24,760
outer disk is destabilized so is the

225
00:11:29,940 --> 00:11:28,180
inner asteroid belt and both of these

226
00:11:32,460 --> 00:11:29,950
classes of bodies then are flung through

227
00:11:34,410 --> 00:11:32,470
the solar system with the icy bodies

228
00:11:36,900 --> 00:11:34,420
going primarily into forming the Kuiper

229
00:11:38,820 --> 00:11:36,910
disk or out to the Oort cloud and of

230
00:11:40,740 --> 00:11:38,830
course many of the asteroids and many of

231
00:11:42,900 --> 00:11:40,750
these bodies me iso disk would then be

232
00:11:45,330 --> 00:11:42,910
flown through the inner solar system and

233
00:11:48,090 --> 00:11:45,340
would bombard the terrestrial planets so

234
00:11:51,540 --> 00:11:48,100
again this this model dynamical model

235
00:11:53,880 --> 00:11:51,550
which has achieved success by resolving

236
00:11:57,270 --> 00:11:53,890
the explanations for about eight or nine

237
00:11:59,910 --> 00:11:57,280
major conundrums about the giant planets

238
00:12:01,770 --> 00:11:59,920

themselves and also their companion

239
00:12:05,490 --> 00:12:01,780
bodies such as the Trojan asteroids and

240
00:12:07,470 --> 00:12:05,500
so on has achieved great acceptance

241
00:12:09,570 --> 00:12:07,480
within the community and so challenge it

242
00:12:13,680 --> 00:12:09,580
presents for this particular webinar is

243
00:12:16,440 --> 00:12:13,690
to keep in mind the grand tack the beast

244
00:12:18,840 --> 00:12:16,450
model I didn't mention the birth cluster

245
00:12:20,790 --> 00:12:18,850
model for origin of the some knob

246
00:12:23,030 --> 00:12:20,800
placement somebody's in the Oort cloud

247
00:12:26,040 --> 00:12:23,040
during the in the son's birth cluster

248
00:12:27,090 --> 00:12:26,050
but these three dynamical models

249
00:12:30,600 --> 00:12:27,100
together have

250
00:12:33,300 --> 00:12:30,610
we change the picture dramatically as to

251
00:12:36,270 --> 00:12:33,310
what we need to know about the primitive

252
00:12:38,490 --> 00:12:36,280
planetesimals and then also their

253
00:12:40,920 --> 00:12:38,500
dynamical delivery and the numbers that

254
00:12:44,550 --> 00:12:40,930
were delivered at various times to the

255
00:12:46,230 --> 00:12:44,560
young earth for example so the issue

256
00:12:49,680 --> 00:12:46,240
then is since that we know they're rich

257
00:12:51,810 --> 00:12:49,690
in organic sandwich in water could they

258
00:12:53,640 --> 00:12:51,820
have delivered those materials to the

259
00:12:55,920 --> 00:12:53,650
terrestrial planets and sufficient

260
00:13:00,660 --> 00:12:55,930
abundance to have influenced the

261
00:13:02,460 --> 00:13:00,670
emergence of life itself okay so let's

262
00:13:04,980 --> 00:13:02,470
move on maybe a lot of things to talk

263
00:13:07,080 --> 00:13:04,990

about so this just reminds you of the

264
00:13:10,320 --> 00:13:07,090
reservoirs today I won't go into that in

265
00:13:12,750 --> 00:13:10,330
detail they're basically two for sure

266
00:13:16,050 --> 00:13:12,760
that namely IG bodies reside in your

267
00:13:19,500 --> 00:13:16,060
cloud in the Kuiper disk and there may

268
00:13:22,890 --> 00:13:19,510
be met some in the main belt as well and

269
00:13:25,530 --> 00:13:22,900
we can look to the grand tack as the

270
00:13:27,390 --> 00:13:25,540
reason why they might be there but we

271
00:13:30,330 --> 00:13:27,400
don't actually have any detection of

272
00:13:33,030 --> 00:13:30,340
water vapor or any other gas released

273
00:13:34,860 --> 00:13:33,040
from any of these active asteroids so

274
00:13:36,990 --> 00:13:34,870
it's not clear yet whether those

275
00:13:39,300 --> 00:13:37,000
asteroids are activated by collisions or

276
00:13:42,090 --> 00:13:39,310
whether some actually are activated by

277
00:13:45,990 --> 00:13:42,100
water and when the asteroid moves

278
00:13:47,790 --> 00:13:46,000
towards its perihelion spizz ition okay

279
00:13:51,390 --> 00:13:47,800
so how do we get at these questions

280
00:13:53,910 --> 00:13:51,400
about the material that is contained

281
00:13:55,500 --> 00:13:53,920
within commentary bodies and these icy

282
00:13:58,200 --> 00:13:55,510
planetesimals and how that might be

283
00:14:01,350 --> 00:13:58,210
delivered to earth well this is just a

284
00:14:03,240 --> 00:14:01,360
take-home message which says you really

285
00:14:06,750 --> 00:14:03,250
don't learn much about the composition

286
00:14:08,040 --> 00:14:06,760
by looking at an image of the object you

287
00:14:10,920 --> 00:14:08,050
know you just learn something about us

288
00:14:14,690 --> 00:14:10,930

it's a history for example this this

289
00:14:17,540 --> 00:14:14,700
object is heavily eroded by mass loss

290
00:14:21,900 --> 00:14:17,550
whereas something like build to

291
00:14:24,660 --> 00:14:21,910
nucleuses as enormous vertical structure

292
00:14:26,790 --> 00:14:24,670
hundreds of meters spires hundreds of

293
00:14:29,220 --> 00:14:26,800
meters of high and so forth and it's

294
00:14:31,440 --> 00:14:29,230
thought to be a pristine not heavily

295
00:14:34,710 --> 00:14:31,450
eroded since it was placed in its

296
00:14:35,519 --> 00:14:34,720
present orbit so what instead one needs

297
00:14:38,309 --> 00:14:35,529
to do is

298
00:14:41,579 --> 00:14:38,319
to begin to look at the chemicals of

299
00:14:44,699 --> 00:14:41,589
which these objects are made and one of

300
00:14:46,860 --> 00:14:44,709
the first Clues it was quantitated

301
00:14:50,699 --> 00:14:46,870
quantitatively derived a taxonomy if you

302
00:14:53,960 --> 00:14:50,709
like was based on not the the primary or

303
00:14:56,160 --> 00:14:53,970
native volatiles from which comets are

304
00:14:59,850 --> 00:14:56,170
composed because when this work was done

305
00:15:03,299 --> 00:14:59,860
it was not possible to measure those one

306
00:15:05,759 --> 00:15:03,309
could only measure the fragments that

307
00:15:08,249 --> 00:15:05,769
derived from those molecules and so C 2

308
00:15:11,549 --> 00:15:08,259
and C n are bright and easily seen in

309
00:15:14,249 --> 00:15:11,559
the optical and so a team led by Mike

310
00:15:17,400 --> 00:15:14,259
Ahern and his collaborators basically

311
00:15:19,439 --> 00:15:17,410
quantified the ratio of c2 CN at number

312
00:15:20,910 --> 00:15:19,449
of comets and showed that for comets

313
00:15:23,730 --> 00:15:20,920

from the Kuiper belt they seem to be

314
00:15:26,910 --> 00:15:23,740
sufficient substantially depleted in

315
00:15:29,369 --> 00:15:26,920
this ratio whereas relatively a smaller

316
00:15:31,829 --> 00:15:29,379
number of Oort cloud comets were so

317
00:15:34,429 --> 00:15:31,839
depleted so this was indication was

318
00:15:37,679 --> 00:15:34,439
suggested that this could be perhaps a

319
00:15:39,059 --> 00:15:37,689
cosmic ganic difference although other

320
00:15:40,920 --> 00:15:39,069
people thought maybe it was due to

321
00:15:43,259 --> 00:15:40,930
processing because of Jupiter family

322
00:15:44,850 --> 00:15:43,269
comments from the Kuiper belt have been

323
00:15:48,809 --> 00:15:44,860
in their orbits for a long time whereas

324
00:15:51,629 --> 00:15:48,819
many of your cloud comets it not so it

325
00:15:56,699 --> 00:15:51,639
also dramatized need for looking at the

326
00:15:59,240 --> 00:15:56,709
individual parent or primary of all

327
00:16:02,549 --> 00:15:59,250
sizes we don't like to call them and

328
00:16:06,569 --> 00:16:02,559
this chart reminds you of the two dozen

329
00:16:11,519 --> 00:16:06,579
or so primary volatiles which have now

330
00:16:13,049 --> 00:16:11,529
been detected in commentary bodies when

331
00:16:14,999 --> 00:16:13,059
they've been vaporized and entered

332
00:16:17,480 --> 00:16:15,009
Tacoma there in the gas phase and they

333
00:16:20,309 --> 00:16:17,490
are then amenable to detection by

334
00:16:23,069 --> 00:16:20,319
looking at their rotation vibrational

335
00:16:25,679 --> 00:16:23,079
emissions or the rotational emissions at

336
00:16:30,990 --> 00:16:25,689
infrared and radio wavelengths

337
00:16:33,509 --> 00:16:31,000
respectively so what's shown here is two

338
00:16:35,429 --> 00:16:33,519

things one is the range of species water

339
00:16:38,009 --> 00:16:35,439
being at the top but the other is the

340
00:16:40,610 --> 00:16:38,019
range of abundance in it given nucleus

341
00:16:43,060 --> 00:16:40,620
and what you see immediately is that

342
00:16:46,480 --> 00:16:43,070
whenever water is used as a mess

343
00:16:48,550 --> 00:16:46,490
Rick you see huge range of abundance of

344
00:16:52,390 --> 00:16:48,560
for example co by a factor of a hundred

345
00:16:55,720 --> 00:16:52,400
in going from one body to another and in

346
00:16:58,450 --> 00:16:55,730
co2 almost a factor of 20 and so on

347
00:17:02,680 --> 00:16:58,460
whereas other molecules show a much

348
00:17:05,020 --> 00:17:02,690
smaller gradient for example hcs there

349
00:17:07,870 --> 00:17:05,030
is by about a factor of 5 and so on we

350
00:17:09,640 --> 00:17:07,880
don't understand this yet we think

351
00:17:11,800 --> 00:17:09,650
perhaps it may be in some cases

352
00:17:13,960 --> 00:17:11,810
cosmogonic and that's of course one of

353
00:17:16,750 --> 00:17:13,970
the key issues in understanding how to

354
00:17:18,220 --> 00:17:16,760
relate these measurements to delivery

355
00:17:22,530 --> 00:17:18,230
from different regions of the

356
00:17:26,650 --> 00:17:22,540
protoplanetary disk to young planets and

357
00:17:31,510 --> 00:17:26,660
delivery goes to the atmospheric content

358
00:17:32,980 --> 00:17:31,520
of those particular objects well I'm

359
00:17:34,900 --> 00:17:32,990
going to skip over this so you can go

360
00:17:38,800 --> 00:17:34,910
back and look at this later this is from

361
00:17:40,210 --> 00:17:38,810
the Akari space observatory and for some

362
00:17:44,430 --> 00:17:40,220
reason I just seem to go into full

363
00:17:46,630 --> 00:17:44,440

screen display here okay that's good and

364
00:17:48,640 --> 00:17:46,640
the key point is that this was a

365
00:17:51,280 --> 00:17:48,650
paradigm shift and our understanding of

366
00:17:54,340 --> 00:17:51,290
comets and occurred the paper was

367
00:17:56,500 --> 00:17:54,350
published in 2012 a half j and until

368
00:17:58,870 --> 00:17:56,510
then no one really understood that co2

369
00:18:01,480 --> 00:17:58,880
was so important relative to water or

370
00:18:05,070 --> 00:18:01,490
that it was so more much more abundant

371
00:18:08,170 --> 00:18:05,080
than co this was a major surprise and

372
00:18:10,300 --> 00:18:08,180
there was some indication from

373
00:18:14,200 --> 00:18:10,310
interstellar chemistry this would be so

374
00:18:16,120 --> 00:18:14,210
but it's generally not clear the degree

375
00:18:18,220 --> 00:18:16,130
to which comets are made of interstellar

376
00:18:20,320 --> 00:18:18,230
material so we don't know whether this

377
00:18:22,300 --> 00:18:20,330
co2 is a heritage of the interstellar

378
00:18:24,400 --> 00:18:22,310
medium or whether it was something that

379
00:18:26,470 --> 00:18:24,410
was easily produced in the

380
00:18:28,690 --> 00:18:26,480
protoplanetary disk for example

381
00:18:30,850 --> 00:18:28,700
reactions between co and 0 h radicals

382
00:18:33,190 --> 00:18:30,860
produce co2 and every collision

383
00:18:35,890 --> 00:18:33,200
essentially and then you can condense

384
00:18:40,750 --> 00:18:35,900
that co2 rapidly on a grain and enter it

385
00:18:44,620 --> 00:18:40,760
into a comet nucleus and this could be !

386
00:18:47,260 --> 00:18:44,630
issue key point is the simultaneity of

387
00:18:48,290 --> 00:18:47,270
measurement and what you really want to

388
00:18:50,090 --> 00:18:48,300

do and this is

389
00:18:52,360 --> 00:18:50,100
is done at infrared wavelengths is to

390
00:18:55,190 --> 00:18:52,370
measure a whole suite of molecule

391
00:18:57,470 --> 00:18:55,200
simultaneously shown on the left here

392
00:18:58,940 --> 00:18:57,480
you see approximately nine molecules

393
00:19:01,580 --> 00:18:58,950
that are measured routinely in every

394
00:19:03,980 --> 00:19:01,590
comet and then others is a total logs

395
00:19:05,840 --> 00:19:03,990
which are more difficult to measure and

396
00:19:09,830 --> 00:19:05,850
they are also targeted as well in common

397
00:19:12,800 --> 00:19:09,840
too common so this gives you the power

398
00:19:14,720 --> 00:19:12,810
to assess how the material is

399
00:19:16,790 --> 00:19:14,730
distributed within the cometary nucleus

400
00:19:19,310 --> 00:19:16,800
by looking at how it's actually

401
00:19:22,040 --> 00:19:19,320
distributed and coming off in the coma

402
00:19:24,920 --> 00:19:22,050
if you see the a polar species coming in

403
00:19:26,300 --> 00:19:24,930
one direction on the polar species in a

404
00:19:28,970 --> 00:19:26,310
different direction from the nucleus

405
00:19:30,680 --> 00:19:28,980
that suggests strongly that they're two

406
00:19:32,750 --> 00:19:30,690
distinct types phases that are not

407
00:19:35,270 --> 00:19:32,760
hitter at home ingeniously mixed within

408
00:19:37,640 --> 00:19:35,280
the nucleus and we do indeed see that in

409
00:19:41,620 --> 00:19:37,650
some comments so that is another part of

410
00:19:45,710 --> 00:19:41,630
the puzzle I'll just to dramatize this

411
00:19:48,820 --> 00:19:45,720
created this cartoon which compares

412
00:19:52,160 --> 00:19:48,830
three Oort cloud comets and everyone

413
00:19:53,690 --> 00:19:52,170

people who don't study comments tend to

414
00:19:55,390 --> 00:19:53,700
think everything in the Oort cloud is

415
00:19:59,630 --> 00:19:55,400
the same in terms of its composition

416
00:20:01,450 --> 00:19:59,640
everything in the Hartley oh I'm sorry

417
00:20:04,490 --> 00:20:01,460
in the Kuiper belt is the same and so on

418
00:20:06,530 --> 00:20:04,500
but if you look at this so it's at the

419
00:20:10,220 --> 00:20:06,540
low end of the diet of the diagram you

420
00:20:14,020 --> 00:20:10,230
see this a particular depiction of the

421
00:20:16,700 --> 00:20:14,030
overall composition of the comet here

422
00:20:18,920 --> 00:20:16,710
where the blue represents the water

423
00:20:20,510 --> 00:20:18,930
vapor and the trace gases are everything

424
00:20:23,660 --> 00:20:20,520
else in the small wedge that's just

425
00:20:26,390 --> 00:20:23,670
above that but if you break that the

426
00:20:28,820 --> 00:20:26,400
trace gas is down comment by comet then

427
00:20:32,080 --> 00:20:28,830
for Hartley 2 for example you find that

428
00:20:35,840 --> 00:20:32,090
co2 comprised almost eighty percent of

429
00:20:38,600 --> 00:20:35,850
the trace gas whereas for garad it was

430
00:20:40,370 --> 00:20:38,610
about a third and four luling about the

431
00:20:42,590 --> 00:20:40,380
same so here you see a dramatic

432
00:20:45,050 --> 00:20:42,600
difference in these three comets from

433
00:20:46,130 --> 00:20:45,060
the same reservoir clearly indicating

434
00:20:49,160 --> 00:20:46,140
that they're quite different their

435
00:20:51,830 --> 00:20:49,170
composition so again if you look at

436
00:20:53,990 --> 00:20:51,840
other molecules different differentiated

437
00:20:55,310 --> 00:20:54,000
by these colors you can see for example

438
00:20:57,560 --> 00:20:55,320

a huge

439
00:21:00,230 --> 00:20:57,570
difference in this particular species as

440
00:21:03,560 --> 00:21:00,240
you go from comet comet to comment so

441
00:21:05,450 --> 00:21:03,570
this is a clear indication of perhaps

442
00:21:07,640 --> 00:21:05,460
they were formed in different regions of

443
00:21:09,140 --> 00:21:07,650
the pillow contrary disk or incorporated

444
00:21:12,080 --> 00:21:09,150
material formed in those different

445
00:21:14,860 --> 00:21:12,090
regions and so on this is part of the

446
00:21:18,500 --> 00:21:14,870
puzzle that we need to get two answers

447
00:21:22,430 --> 00:21:18,510
okay so I've kind of mentioned several

448
00:21:25,610 --> 00:21:22,440
of these paradigm shifts have occurred

449
00:21:27,890 --> 00:21:25,620
in very recent time that are informing

450
00:21:29,780 --> 00:21:27,900
us about the nature of these bodies and

451
00:21:32,300 --> 00:21:29,790
how they can relate to understanding

452
00:21:37,160 --> 00:21:32,310
their role in delivering such material

453
00:21:40,550 --> 00:21:37,170
to the young planets now we've tried to

454
00:21:42,050 --> 00:21:40,560
group these commentary bodies the

455
00:21:44,300 --> 00:21:42,060
infrared teams have together put

456
00:21:49,790 --> 00:21:44,310
together approximately database on

457
00:21:52,520 --> 00:21:49,800
roughly 25 to 30 comments and for the

458
00:21:56,570 --> 00:21:52,530
ones that are best characterized we're

459
00:21:59,870 --> 00:21:56,580
able to show that in fact the ethane for

460
00:22:02,600 --> 00:21:59,880
example if one just shows the number of

461
00:22:04,610 --> 00:22:02,610
comets and the versus the abundance of

462
00:22:06,290 --> 00:22:04,620
ethane relative to water you can see

463
00:22:08,090 --> 00:22:06,300

this is a real clumping in this area at

464
00:22:10,460 --> 00:22:08,100
around point six percent relative to

465
00:22:12,680 --> 00:22:10,470
water but there are several comments

466
00:22:15,380 --> 00:22:12,690
that are highly enriched by factors of

467
00:22:17,720 --> 00:22:15,390
two or so and others that are not we

468
00:22:21,710 --> 00:22:17,730
depleted and we see the same thing and

469
00:22:26,260 --> 00:22:21,720
methanol both or normal as we call it

470
00:22:30,409 --> 00:22:26,270
enriched and depleted if one moves on to

471
00:22:35,389 --> 00:22:30,419
look at these order the is actually

472
00:22:42,169 --> 00:22:35,399
17 different things either steal lemons

473
00:22:43,820 --> 00:22:42,179
review what is he someone dude please

474
00:22:50,690 --> 00:22:43,830
are getting a lot of pick up on a mic

475
00:22:53,180 --> 00:22:50,700
consumer sorry about that Mike I'm is

476
00:22:57,379 --> 00:22:53,190
going to meet that line for now okay

477
00:22:59,479 --> 00:22:57,389
thanks the green region represents CEO

478
00:23:01,039 --> 00:22:59,489
rich comets which are as you see they're

479
00:23:05,149 --> 00:23:01,049
rare in this population we only have

480
00:23:08,359 --> 00:23:05,159
four of them a total of the 18 display

481
00:23:10,729 --> 00:23:08,369
here so less than 20 about a quarter or

482
00:23:13,759 --> 00:23:10,739
perhaps twenty percent of the comments

483
00:23:15,849 --> 00:23:13,769
or CEO rich but once when you look for

484
00:23:18,680 --> 00:23:15,859
correlations of molecule to molecule

485
00:23:19,970 --> 00:23:18,690
really the thing that jumps out at you

486
00:23:24,349 --> 00:23:19,980
if you look at this for a little while

487
00:23:26,720 --> 00:23:24,359
is it hcn is correlated with ethane but

488
00:23:28,909 --> 00:23:26,730

not with CEO and not with methane for

489
00:23:30,769 --> 00:23:28,919
example and so this suggests that

490
00:23:32,029 --> 00:23:30,779
looking at different comets in there in

491
00:23:34,249 --> 00:23:32,039
the correlation of these two molecules

492
00:23:36,590 --> 00:23:34,259
might in fact reveal some new

493
00:23:41,499 --> 00:23:36,600
information and sure enough when you do

494
00:23:44,180 --> 00:23:41,509
that you see that again the three bodies

495
00:23:46,609 --> 00:23:44,190
there's a group that has a high ratio

496
00:23:50,570 --> 00:23:46,619
for both this is could be regarded as a

497
00:23:52,519 --> 00:23:50,580
mixing line but most comets are down in

498
00:23:55,129 --> 00:23:52,529
this region of the mixing line only a

499
00:23:59,239 --> 00:23:55,139
few are up at the high end and there are

500
00:24:03,169 --> 00:23:59,249
a few of roads if you like which have

501
00:24:05,149 --> 00:24:03,179
very little f ain but a lot of hcn we

502
00:24:09,109 --> 00:24:05,159
think this is a different group of

503
00:24:11,119 --> 00:24:09,119
comets we've called them depleted comets

504
00:24:12,979 --> 00:24:11,129
but we think there is another story

505
00:24:15,859 --> 00:24:12,989
behind this and we're trying to unravel

506
00:24:21,529 --> 00:24:15,869
with the line of evidence that we have a

507
00:24:24,200 --> 00:24:21,539
half perhaps these are formed the HCM in

508
00:24:26,299 --> 00:24:24,210
some comments is actually not a primary

509
00:24:30,379 --> 00:24:26,309
species that Rather's formed in the coma

510
00:24:31,369 --> 00:24:30,389
by some mechanisms well let's move on we

511
00:24:33,169 --> 00:24:31,379
don't really want to get into the

512
00:24:37,340 --> 00:24:33,179
details of all this just to give you the

513
00:24:39,710 --> 00:24:37,350

broad brush overview another key metric

514
00:24:41,240 --> 00:24:39,720
we look at cosmogonic parameters

515
00:24:44,720 --> 00:24:41,250
these are things we think remain

516
00:24:47,260 --> 00:24:44,730
unchanged from the time of formation the

517
00:24:49,580 --> 00:24:47,270
you know any molecule that has

518
00:24:51,409 --> 00:24:49,590
symmetrically located hydrogen atoms

519
00:24:53,779 --> 00:24:51,419
will have nuclear spins that can be

520
00:24:57,620 --> 00:24:53,789
aligned or anti aligned and under

521
00:25:00,710 --> 00:24:57,630
exchange those things are in that ratios

522
00:25:03,320 --> 00:25:00,720
invariant so this gives rise to a

523
00:25:05,480 --> 00:25:03,330
temperature which one can call the

524
00:25:07,039 --> 00:25:05,490
nuclear spin temperature and the key

525
00:25:10,669 --> 00:25:07,049
point is that if one looks at different

526
00:25:13,520 --> 00:25:10,679
primaries such as ammonia shown here the

527
00:25:16,820 --> 00:25:13,530
ortho para ratio for ammonia and various

528
00:25:19,130 --> 00:25:16,830
comets approaches the equilibrium value

529
00:25:21,710 --> 00:25:19,140
at temperatures above about 35 Kelvin

530
00:25:25,399 --> 00:25:21,720
water approaches a different value this

531
00:25:27,950 --> 00:25:25,409
curve and also can be equilibrated

532
00:25:30,049 --> 00:25:27,960
roughly 50 Calvin but if you take the

533
00:25:31,399 --> 00:25:30,059
temp and spin temperatures and compare

534
00:25:34,159 --> 00:25:31,409
the one with another in these two

535
00:25:37,399 --> 00:25:34,169
species within a given comet what's

536
00:25:39,890 --> 00:25:37,409
remarkable is that they clump in a very

537
00:25:42,620 --> 00:25:39,900
narrow region of this temper at this

538
00:25:44,830 --> 00:25:42,630

space and so this tells you that these

539
00:25:47,840 --> 00:25:44,840
independent molecular species are

540
00:25:50,330 --> 00:25:47,850
registering a same nuclear spin

541
00:25:52,490 --> 00:25:50,340
temperature even though their

542
00:25:54,830 --> 00:25:52,500
chemistry's are significantly different

543
00:25:56,710 --> 00:25:54,840
and we think that's a very important

544
00:25:59,029 --> 00:25:56,720
clue into the formation mechanism

545
00:26:03,289 --> 00:25:59,039
another thing it's very hard to change

546
00:26:06,430 --> 00:26:03,299
in these Isis is the isotopic ratios and

547
00:26:08,840 --> 00:26:06,440
the key thing there is to look at the

548
00:26:11,299 --> 00:26:08,850
ideally the isotopes and individual

549
00:26:13,640 --> 00:26:11,309
species so we'll take a quick look at

550
00:26:16,899 --> 00:26:13,650
what is known at one or two of these

551
00:26:21,620 --> 00:26:16,909
isotopes in particular nitrogen carbon

552
00:26:24,860 --> 00:26:21,630
and hydrogen so for example here is a

553
00:26:28,399 --> 00:26:24,870
survey done by Manfred Shaheen and their

554
00:26:30,950 --> 00:26:28,409
collaborators and for 18 comets they

555
00:26:33,470 --> 00:26:30,960
showed that the carbon 12 13 ratio

556
00:26:35,240 --> 00:26:33,480
measured in situ or cm and by the way

557
00:26:38,060 --> 00:26:35,250
keep in mind these are minor

558
00:26:40,430 --> 00:26:38,070
constituents there are fragments of may

559
00:26:43,640 --> 00:26:40,440
be produced in part from dust we really

560
00:26:46,649 --> 00:26:43,650
don't know all the origins of these two

561
00:26:49,049 --> 00:26:46,659
radicals but the bottom line is that

562
00:26:51,719 --> 00:26:49,059
the mean mean value is in good agreement

563
00:26:55,200 --> 00:26:51,729

with the terrestrial ratio for carbon-12

564
00:26:57,839 --> 00:26:55,210
carbon-13 is that true for nitrogen no

565
00:27:00,599 --> 00:26:57,849
it's not in fact the earth itself is

566
00:27:03,899 --> 00:27:00,609
enriched dramatically relative to the

567
00:27:07,979 --> 00:27:03,909
cosmic value by a factor of two and the

568
00:27:12,180 --> 00:27:07,989
Comets are enriched in that ratio 14 15

569
00:27:14,009 --> 00:27:12,190
and by another factor of two so the 1459

570
00:27:17,789 --> 00:27:14,019
ratio is about a hundred and forty in

571
00:27:20,759 --> 00:27:17,799
the mean there's been no explanation for

572
00:27:22,200 --> 00:27:20,769
this Nora's have been any explanation

573
00:27:25,409 --> 00:27:22,210
for the enrichment of the earth itself

574
00:27:28,080 --> 00:27:25,419
in terms of nitrogen vers versus the

575
00:27:30,509 --> 00:27:28,090
cosmic value so this represents a puzzle

576
00:27:32,039 --> 00:27:30,519
as to why the Comets are different from

577
00:27:35,099 --> 00:27:32,049
the earth did they have a role in

578
00:27:36,839 --> 00:27:35,109
enhancing the earth above the nebular

579
00:27:39,869 --> 00:27:36,849
value is that the the reason the earth

580
00:27:42,719 --> 00:27:39,879
is high in nitrogen 14 verse 15 ratio or

581
00:27:44,849 --> 00:27:42,729
not Mike it looks like penny may have

582
00:27:49,109 --> 00:27:44,859
raised your hand oh we have a hand

583
00:27:50,460 --> 00:27:49,119
raised light up no it's gone no penny

584
00:27:53,190 --> 00:27:50,470
the lines are open if you want to speak

585
00:27:56,609 --> 00:27:53,200
over the phone okay thanks um yeah I was

586
00:28:00,119 --> 00:27:56,619
just wondering you know what extent

587
00:28:03,330 --> 00:28:00,129
would we multiple EC the preservation of

588
00:28:07,369 --> 00:28:03,340

you were just addressing the relative

589
00:28:09,960 --> 00:28:07,379
isotope in rock record of highly

590
00:28:12,710 --> 00:28:09,970
geologically active bodies holder forces

591
00:28:15,060 --> 00:28:12,720
what we might see in much less

592
00:28:18,169 --> 00:28:15,070
geologically active bodies like the

593
00:28:20,700 --> 00:28:18,179
surfaces of icy moon yeah I think

594
00:28:22,440 --> 00:28:20,710
probably Jamie's better qualified to

595
00:28:25,649 --> 00:28:22,450
talk to the meteoritic record on that

596
00:28:28,440 --> 00:28:25,659
yeah but as far as geologically I'd your

597
00:28:33,779 --> 00:28:28,450
body's I don't have much to say about

598
00:28:37,830 --> 00:28:33,789
that okay a good question yeah so penny

599
00:28:41,249 --> 00:28:37,840
I don't know that actually have not

600
00:28:45,509 --> 00:28:41,259
myself looked at the literature as to

601
00:28:48,719 --> 00:28:45,519
the where that terrestrial ratio comes

602
00:28:50,729 --> 00:28:48,729
from of course as we all know nitrogen

603
00:28:51,289 --> 00:28:50,739
gas is the principal carrier in the

604
00:28:53,600 --> 00:28:51,299
atmos

605
00:28:57,019 --> 00:28:53,610
but I have not looked at what's what the

606
00:29:00,950 --> 00:28:57,029
rock record tells us perhaps unwelcome I

607
00:29:03,619 --> 00:29:00,960
could could clarify that point wells in

608
00:29:07,989 --> 00:29:03,629
Helena and it seems like an tme that

609
00:29:11,029 --> 00:29:07,999
maybe this is you know you know in which

610
00:29:13,340 --> 00:29:11,039
some group within the asteroid you've

611
00:29:15,619 --> 00:29:13,350
ever happens I'll be looking at it but I

612
00:29:18,019 --> 00:29:15,629
haven't read every single paper so i'm

613
00:29:20,629 --> 00:29:18,029

not sure if anybody else has books with

614
00:29:23,979 --> 00:29:20,639
that issue that it seems it's important

615
00:29:27,859 --> 00:29:23,989
to try to see what if anything of that

616
00:29:30,680 --> 00:29:27,869
more influence of these these potential

617
00:29:33,229 --> 00:29:30,690
grocery deliveries to the early Earth

618
00:29:35,210 --> 00:29:33,239
may have been preserved in the rock

619
00:29:38,570 --> 00:29:35,220
record than I are or where we cannot

620
00:29:40,159 --> 00:29:38,580
expect to actually people well I guess

621
00:29:42,919 --> 00:29:40,169
if one wants to go back to the

622
00:29:45,289 --> 00:29:42,929
moon-forming event you know you could

623
00:29:47,299 --> 00:29:45,299
argue this has been argued by various

624
00:29:50,060 --> 00:29:47,309
people that significant fraction of the

625
00:29:53,090 --> 00:29:50,070
outgassing of the earth had occurred by

626
00:29:55,909 --> 00:29:53,100
then and a lot of that primordial

627
00:29:59,869 --> 00:29:55,919
atmosphere was removed but during that

628
00:30:02,359 --> 00:29:59,879
collision Mike and so then if you

629
00:30:05,090 --> 00:30:02,369
deliver a new atmosphere you would think

630
00:30:07,789 --> 00:30:05,100
that or at least augmented dramatically

631
00:30:09,649 --> 00:30:07,799
then you would think that the nitrogen

632
00:30:11,599 --> 00:30:09,659
meso topic ratio and the incoming

633
00:30:15,619 --> 00:30:11,609
material would be an important thing to

634
00:30:18,109 --> 00:30:15,629
know to compare with the n2 gas on the

635
00:30:20,119 --> 00:30:18,119
earth today so I'm going to say this if

636
00:30:21,680 --> 00:30:20,129
the point of today's webinar is to make

637
00:30:23,960 --> 00:30:21,690
sure that we're listing important

638
00:30:26,119 --> 00:30:23,970

questions in the roadmap not necessarily

639
00:30:27,919 --> 00:30:26,129
to answer those questions today so

640
00:30:30,879 --> 00:30:27,929
that's this is a good thing to make sure

641
00:30:32,989 --> 00:30:30,889
is captured in the document that this is

642
00:30:34,669 --> 00:30:32,999
understanding what the Federation

643
00:30:37,399 --> 00:30:34,679
without the topic signatures is likely

644
00:30:38,989 --> 00:30:37,409
to be make sure that that's captured is

645
00:30:42,200 --> 00:30:38,999
research that needs to be done and

646
00:30:45,799 --> 00:30:42,210
Francis a hand raised their present

647
00:30:49,340 --> 00:30:45,809
Gardner yeah I was just going to say

648
00:30:50,960 --> 00:30:49,350
what you just said the questions open I

649
00:30:52,820 --> 00:30:50,970
don't think there is quite an answer I

650
00:30:55,909 --> 00:30:52,830
for earth it's a little complicated

651
00:30:59,570 --> 00:30:55,919
because things have been reset through

652
00:31:02,340 --> 00:30:59,580
geologic time and volatile isotopes are

653
00:31:05,340 --> 00:31:02,350
pretty easy to change

654
00:31:08,690 --> 00:31:05,350
we you know I know that there are very

655
00:31:11,370 --> 00:31:08,700
abilities among at least Mars and Earth

656
00:31:13,260 --> 00:31:11,380
but i'm not sure we know exactly where

657
00:31:16,650 --> 00:31:13,270
those differences come from at this

658
00:31:18,690 --> 00:31:16,660
moment we should just make sure that

659
00:31:20,100 --> 00:31:18,700
when the final version of this document

660
00:31:22,260 --> 00:31:20,110
is written the best captured as a

661
00:31:30,169 --> 00:31:22,270
question that's needing some more

662
00:31:37,919 --> 00:31:33,779
all right so enough said about carbon

663
00:31:42,090 --> 00:31:37,929

and nitrogen i do want to caution people

664
00:31:45,419 --> 00:31:42,100
about the accepting the values that on

665
00:31:50,159 --> 00:31:45,429
the face of them for example these check

666
00:31:54,390 --> 00:31:50,169
marks on the right compare some issues

667
00:31:57,240 --> 00:31:54,400
of bulk IDPs and build to entity and 14

668
00:31:59,720 --> 00:31:57,250
15 is consistent with terrestrial if if

669
00:32:02,039 --> 00:31:59,730
you look at the actual the over the

670
00:32:04,350 --> 00:32:02,049
shown on the left here is kind of an

671
00:32:09,419 --> 00:32:04,360
oval this is from a figure by dominique

672
00:32:12,810 --> 00:32:09,429
pocket lor-van and so essentially the

673
00:32:14,610 --> 00:32:12,820
bulk overlaps the terrestrial value the

674
00:32:16,380 --> 00:32:14,620
mean of course is a little different but

675
00:32:18,720 --> 00:32:16,390
there does there's an issue as to

676
00:32:22,740 --> 00:32:18,730
whether in fact the overlap is

677
00:32:24,180 --> 00:32:22,750
sufficient at the one signal level the

678
00:32:27,270 --> 00:32:24,190
other point to keep in mind is that

679
00:32:30,149 --> 00:32:27,280
thomas ammonia is the principal carrier

680
00:32:32,970 --> 00:32:30,159
volatile nitrogen and we have no idea

681
00:32:35,070 --> 00:32:32,980
what it's 15 nitrogen enrichment maybe

682
00:32:38,490 --> 00:32:35,080
in comets so we really don't even know

683
00:32:41,360 --> 00:32:38,500
how to compare the dominant carrier of

684
00:32:44,610 --> 00:32:41,370
ulta nitrogen comets with the

685
00:32:47,399 --> 00:32:44,620
atmospheric value in the earth the next

686
00:32:49,710 --> 00:32:47,409
point which people often tend over

687
00:32:51,690 --> 00:32:49,720
forget is that the origins of commentary

688
00:32:54,960 --> 00:32:51,700

CNR uncertain which comes up to the

689
00:32:57,470 --> 00:32:54,970
point that was just made namely CN can

690
00:33:01,950 --> 00:32:57,480
impart come from ice like HCM

691
00:33:06,299 --> 00:33:01,960
association of the precursor or from the

692
00:33:07,270 --> 00:33:06,309
rock the dust grains are coral CM jets

693
00:33:09,910 --> 00:33:07,280
and various

694
00:33:12,580 --> 00:33:09,920
correlated with dust grains and so this

695
00:33:15,550 --> 00:33:12,590
raises an issue as to whether the CN is

696
00:33:18,100 --> 00:33:15,560
in fact really a faithful measure of the

697
00:33:20,560 --> 00:33:18,110
overall bulk in a comment or whether

698
00:33:24,220 --> 00:33:20,570
when once we begin to measure ammonia

699
00:33:26,650 --> 00:33:24,230
will see different value and final point

700
00:33:29,350 --> 00:33:26,660
which I mentioned briefly in passing was

701
00:33:31,300 --> 00:33:29,360
the fact that we think that HCN may be

702
00:33:36,900 --> 00:33:31,310
produced from Siena nakoma so to turn

703
00:33:39,370 --> 00:33:36,910
that around an important sub from a

704
00:33:42,070 --> 00:33:39,380
comet and what didn't what proportions

705
00:33:45,100 --> 00:33:42,080
is stored in the nucleus as opposed to

706
00:33:48,460 --> 00:33:45,110
be produced in the coma from reactions

707
00:33:50,650 --> 00:33:48,470
such as cyanogen plus a hydrocarbon such

708
00:33:53,790 --> 00:33:50,660
as methane my question just got typed in

709
00:33:58,300 --> 00:33:53,800
on the cat wonder there okay so we have

710
00:34:00,450 --> 00:33:58,310
is it Ron yes follow talisman syllabus

711
00:34:02,740 --> 00:34:00,460
have similarities what you display for

712
00:34:05,950 --> 00:34:02,750
comments does a suggestive commentary

713
00:34:07,870 --> 00:34:05,960

origin for Enceladus volatiles that I

714
00:34:10,780 --> 00:34:07,880
think is an interesting question one

715
00:34:13,270 --> 00:34:10,790
that we've kicked around here in my

716
00:34:15,370 --> 00:34:13,280
group at Goddard quite a lot my

717
00:34:19,600 --> 00:34:15,380
understanding right now is that hunter

718
00:34:22,270 --> 00:34:19,610
wait who is the P I on the instrument

719
00:34:27,130 --> 00:34:22,280
that's measured these volatiles from

720
00:34:31,870 --> 00:34:27,140
Cassini now things that essentially most

721
00:34:36,000 --> 00:34:31,880
or even all of the smaller molecules can

722
00:34:39,240 --> 00:34:36,010
be derived by destruction of benzene and

723
00:34:42,909 --> 00:34:39,250
most of what they see as hydrocarbons

724
00:34:45,340 --> 00:34:42,919
there is some water and so it's not

725
00:34:48,010 --> 00:34:45,350
clear to me now even what is being

726
00:34:50,880 --> 00:34:48,020
released from Enceladus because by the

727
00:34:54,940 --> 00:34:50,890
time you measure something in the plumes

728
00:34:57,580 --> 00:34:54,950
it could have only a in direct relation

729
00:34:59,920 --> 00:34:57,590
to the material that actually was being

730
00:35:04,630 --> 00:34:59,930
released from the base of the plume

731
00:35:06,490 --> 00:35:04,640
itself so but nevertheless the idea of

732
00:35:08,950 --> 00:35:06,500
the cometary origin foreign solidus has

733
00:35:10,180 --> 00:35:08,960
been suggested

734
00:35:12,000 --> 00:35:10,190
I think it's actually even in the

735
00:35:15,670 --> 00:35:12,010
literature but I think we don't have the

736
00:35:19,780 --> 00:35:15,680
hard evidence yet to test that

737
00:35:21,609 --> 00:35:19,790
hypothesis so that's something that one

738
00:35:23,650 --> 00:35:21,619

would like to do and of course now that

739
00:35:27,370 --> 00:35:23,660
we know there are plumes of water on

740
00:35:30,370 --> 00:35:27,380
Europa at the South Pole which was just

741
00:35:32,829 --> 00:35:30,380
published in science we'd like to know

742
00:35:38,980 --> 00:35:32,839
whether other species are being released

743
00:35:43,750 --> 00:35:38,990
as well ok so now comparing these two

744
00:35:46,990 --> 00:35:43,760
metrics has been done by sanaka and

745
00:35:50,520 --> 00:35:47,000
allocated company and what's interesting

746
00:35:53,500 --> 00:35:50,530
is that suddenly what you see is that

747
00:35:55,990 --> 00:35:53,510
for a variety of comets and these by the

748
00:35:58,540 --> 00:35:56,000
way are grouped by orbiting blast and

749
00:36:01,390 --> 00:35:58,550
dissemination areas we get good

750
00:36:04,720 --> 00:36:01,400
correlation between opr clustering and

751
00:36:07,390 --> 00:36:04,730
the isotopic ratio of nitrogen but there

752
00:36:10,089 --> 00:36:07,400
is one comet these are two fragments of

753
00:36:13,450 --> 00:36:10,099
Russian Blackmon 3 which is an ecliptic

754
00:36:15,010 --> 00:36:13,460
comet that's lit they're totally

755
00:36:17,829 --> 00:36:15,020
different so it's quite of something

756
00:36:20,020 --> 00:36:17,839
going on we don't understand and until

757
00:36:22,060 --> 00:36:20,030
we do understand it we can't assess this

758
00:36:24,490 --> 00:36:22,070
take this is a metric to assess what

759
00:36:27,010 --> 00:36:24,500
might be delivered to the earth now

760
00:36:30,099 --> 00:36:27,020
let's just touch on hydrogen and the d2h

761
00:36:33,160 --> 00:36:30,109
ratio because this is a key metric for

762
00:36:35,859 --> 00:36:33,170
many studies not just for commentary

763
00:36:39,400 --> 00:36:35,869

Isis and so on this is this is work done

764
00:36:42,700 --> 00:36:39,410
by Olivier mousses and in fact on the

765
00:36:44,200 --> 00:36:42,710
right panel of showing the d2h ratio is

766
00:36:47,970 --> 00:36:44,210
a function of distance from the young

767
00:36:52,660 --> 00:36:47,980
son and this already incorporated

768
00:36:55,300 --> 00:36:52,670
something like five to fourteen au which

769
00:36:56,890 --> 00:36:55,310
was the region for the giant planets at

770
00:37:00,130 --> 00:36:56,900
the beginning of the nice model

771
00:37:02,680 --> 00:37:00,140
dynamical simulation we already know

772
00:37:05,079 --> 00:37:02,690
from the case of Saturn what the beast

773
00:37:07,930 --> 00:37:05,089
no value is its basis i'm sorry what the

774
00:37:10,780 --> 00:37:07,940
dth ratio is it's been measured to be be

775
00:37:13,740 --> 00:37:10,790
slow and methane very accurately

776
00:37:18,000 --> 00:37:13,750
untighten so it's right about where the

777
00:37:20,220 --> 00:37:18,010
arrow is now right about there drupal

778
00:37:23,640 --> 00:37:20,230
is usually taken to be the nebular value

779
00:37:26,490 --> 00:37:23,650
and that's a roughly two times 7-5 I

780
00:37:29,880 --> 00:37:26,500
don't know why he has this would be a

781
00:37:31,740 --> 00:37:29,890
water model at the position of Jupiter

782
00:37:34,950 --> 00:37:31,750
but of course Jupiter itself is really

783
00:37:40,430 --> 00:37:34,960
dominated by hydrogen which is from the

784
00:37:44,130 --> 00:37:40,440
nebula was taken as the value for nebula

785
00:37:45,810 --> 00:37:44,140
is it for comments the issue is how do

786
00:37:49,590 --> 00:37:45,820
they compare with the terrestrial water

787
00:37:52,670 --> 00:37:49,600
and if you ask that question three years

788
00:37:56,760 --> 00:37:52,680

ago the answer would have been

789
00:37:59,790 --> 00:37:56,770
encompassed by this lips to the right

790
00:38:02,190 --> 00:37:59,800
here that for total of seven comets the

791
00:38:04,590 --> 00:38:02,200
mean value is twice enriched relative to

792
00:38:09,150 --> 00:38:04,600
terrestrial water and so this led people

793
00:38:11,220 --> 00:38:09,160
to assess the possibility of delivery of

794
00:38:14,220 --> 00:38:11,230
our associates by cometary impact is

795
00:38:16,110 --> 00:38:14,230
being quite small affleck roughly ten

796
00:38:20,010 --> 00:38:16,120
percent of her ass ocean water could

797
00:38:23,400 --> 00:38:20,020
come from comets of this type what and

798
00:38:25,800 --> 00:38:23,410
when Hartley 2 was active Herschel

799
00:38:28,290 --> 00:38:25,810
measured the D to weight ratio and water

800
00:38:30,540 --> 00:38:28,300
released from hardly to which is a

801
00:38:33,300 --> 00:38:30,550
Kuiper belt object and bingo it was

802
00:38:37,020 --> 00:38:33,310
exactly coincident with the value of

803
00:38:40,560 --> 00:38:37,030
east mall with in error and so at this

804
00:38:43,020 --> 00:38:40,570
point people who know little about comet

805
00:38:44,940 --> 00:38:43,030
said aha this could mean that you know

806
00:38:48,090 --> 00:38:44,950
comets are responsible for its oceans

807
00:38:51,570 --> 00:38:48,100
after all but the real issue here is

808
00:38:53,640 --> 00:38:51,580
that one comet does not make a mean we

809
00:38:57,780 --> 00:38:53,650
don't really know what the diversity of

810
00:39:00,120 --> 00:38:57,790
do H is within Kuiper belt population if

811
00:39:02,070 --> 00:39:00,130
you don't know what the mean value is we

812
00:39:03,840 --> 00:39:02,080
we know something more about where those

813
00:39:05,900 --> 00:39:03,850

bodies came from and how they were

814
00:39:08,940 --> 00:39:05,910
delivered to the Kuiper belt through the

815
00:39:10,590 --> 00:39:08,950
dynamical models Oh yet don't know how

816
00:39:12,330 --> 00:39:10,600
many of those bodies could have been

817
00:39:15,630 --> 00:39:12,340
delivered to the terrestrial planets

818
00:39:18,450 --> 00:39:15,640
during that event so there are those two

819
00:39:22,890 --> 00:39:18,460
things that are some questions that need

820
00:39:24,100 --> 00:39:22,900
a significant work in order to help to

821
00:39:26,740 --> 00:39:24,110
assess

822
00:39:31,450 --> 00:39:26,750
a question of where deters get its water

823
00:39:34,150 --> 00:39:31,460
and it's organic inventory so I've kind

824
00:39:37,930 --> 00:39:34,160
of captured those caveats and cautions

825
00:39:39,040 --> 00:39:37,940
here you can look at those at your

826
00:39:41,890 --> 00:39:39,050
letter I don't want to take any more

827
00:39:46,240 --> 00:39:41,900
time at this point to do it let's move

828
00:39:48,100 --> 00:39:46,250
on towards the refractory material and I

829
00:39:50,170 --> 00:39:48,110
have just two slides on comets and then

830
00:39:51,910 --> 00:39:50,180
Jamie's going to take over and because

831
00:39:56,400 --> 00:39:51,920
she has much more to say about this

832
00:39:59,790 --> 00:39:56,410
stuver and her colleagues work on the

833
00:40:02,800 --> 00:39:59,800
organics and primitive meteorites and

834
00:40:06,550 --> 00:40:02,810
and in the start of samples but

835
00:40:10,170 --> 00:40:06,560
fundamentally crystal silicates come in

836
00:40:13,450 --> 00:40:10,180
two forms crystalline or amorphous and

837
00:40:16,510 --> 00:40:13,460
it's been a mantra for a long time that

838
00:40:19,660 --> 00:40:16,520

if one sees crystal and silicates and

839
00:40:22,660 --> 00:40:19,670
comets they must have come from the near

840
00:40:26,730 --> 00:40:22,670
Sun location and this applies outward

841
00:40:31,690 --> 00:40:29,230
protoplanetary disk to the outer comet

842
00:40:34,030 --> 00:40:31,700
forming region that was of course the

843
00:40:37,570 --> 00:40:34,040
natural when comet when the giant

844
00:40:40,360 --> 00:40:37,580
planets didn't move around when comets

845
00:40:44,260 --> 00:40:40,370
were always formed far from the young

846
00:40:46,300 --> 00:40:44,270
son or evolve son and so on so this also

847
00:40:48,940 --> 00:40:46,310
has to be re-examined in the light of

848
00:40:51,610 --> 00:40:48,950
all these new models and so on but

849
00:40:53,730 --> 00:40:51,620
nevertheless it is interesting that the

850
00:40:56,740 --> 00:40:53,740
crystal silicates have been seen in

851
00:40:59,020 --> 00:40:56,750
comets that have origin in the Kuiper

852
00:41:00,360 --> 00:40:59,030
belt that's where they form does it mean

853
00:41:02,470 --> 00:41:00,370
where the dust form to where the

854
00:41:05,980 --> 00:41:02,480
volatiles condense but that's where the

855
00:41:11,410 --> 00:41:05,990
comet itself formed so this presents a

856
00:41:13,680 --> 00:41:11,420
major in itself now the mineralogy of

857
00:41:17,230 --> 00:41:13,690
those dust particles is the other

858
00:41:21,780 --> 00:41:17,240
interesting part of that some inclusions

859
00:41:23,890 --> 00:41:21,790
have been used to identify interstellar

860
00:41:26,680 --> 00:41:23,900
particles that were included within the

861
00:41:27,740 --> 00:41:26,690
return common sense others are nebular

862
00:41:29,720 --> 00:41:27,750
origin and

863
00:41:31,790 --> 00:41:29,730

I think Jamie will say a lot more about

864
00:41:35,090 --> 00:41:31,800
that but just to stick with the

865
00:41:36,950 --> 00:41:35,100
silicates for a minute the the Carnegie

866
00:41:42,410 --> 00:41:36,960
group is and others have demonstrated

867
00:41:45,230 --> 00:41:42,420
that the dust in comet Bill 2 is formed

868
00:41:48,230 --> 00:41:45,240
within probably about seven solar radii

869
00:41:50,540 --> 00:41:48,240
have the young son so that stuff is

870
00:41:52,700 --> 00:41:50,550
definitely not interstellar up for some

871
00:41:57,110 --> 00:41:52,710
of the high nitrogen 15 inclusions

872
00:42:00,230 --> 00:41:57,120
perhaps so I think why don't you go

873
00:42:03,080 --> 00:42:00,240
ahead actually try to keep my comments

874
00:42:05,330 --> 00:42:03,090
very brief and it's focused on some of

875
00:42:08,240 --> 00:42:05,340
the questions in this road map document

876
00:42:09,710 --> 00:42:08,250
that address delivery of organics by icy

877
00:42:12,200 --> 00:42:09,720
bodies and the chemistry with you on an

878
00:42:15,020 --> 00:42:12,210
icy bodies in order to do that I went to

879
00:42:17,150 --> 00:42:15,030
looking at meteorites as well part of

880
00:42:18,890 --> 00:42:17,160
this is because analysis of organic

881
00:42:21,560 --> 00:42:18,900
compounds in comets had been primarily

882
00:42:23,600 --> 00:42:21,570
limited to volatile and spectroscopic

883
00:42:25,670 --> 00:42:23,610
measurements that can be made with the

884
00:42:27,110 --> 00:42:25,680
exception of the material returned by

885
00:42:31,400 --> 00:42:27,120
the Stardust mission from the ville to

886
00:42:33,020 --> 00:42:31,410
coma the startups allowed us to get a

887
00:42:35,300 --> 00:42:33,030
little bit of more compound specific

888
00:42:37,250 --> 00:42:35,310

organic identification of some of the

889
00:42:40,130 --> 00:42:37,260
complex organics for example the amino

890
00:42:42,260 --> 00:42:40,140
acid glycine was detected but there's

891
00:42:45,020 --> 00:42:42,270
still a lot we don't know about the

892
00:42:47,360 --> 00:42:45,030
prebiotic chemistry some of the larger

893
00:42:49,550 --> 00:42:47,370
organics that might be present in these

894
00:42:52,750 --> 00:42:49,560
icy bodies and this road map document is

895
00:42:55,550 --> 00:42:52,760
talking about the potential delivery of

896
00:42:58,970 --> 00:42:55,560
this type of material from RC bodies and

897
00:43:01,070 --> 00:42:58,980
from other meteorites to the early Earth

898
00:43:03,020 --> 00:43:01,080
so I thought it looks just a little bit

899
00:43:05,270 --> 00:43:03,030
at some of what we know about meteoritic

900
00:43:06,980 --> 00:43:05,280
organics what clues they give us about

901
00:43:08,630 --> 00:43:06,990
the type of prebiotic chemistry that

902
00:43:11,750 --> 00:43:08,640
might be going on in these bodies and

903
00:43:14,800 --> 00:43:11,760
what questions shall remain that we hope

904
00:43:17,360 --> 00:43:14,810
the roadmap will address in the future

905
00:43:19,070 --> 00:43:17,370
so I wanted to point out here that most

906
00:43:21,440 --> 00:43:19,080
of the organic studies that have been

907
00:43:26,350 --> 00:43:21,450
done on meteorites are on carbonaceous

908
00:43:30,740 --> 00:43:26,360
chondrite which let's do this my pointer

909
00:43:33,020 --> 00:43:30,750
which are subdivided into a sub groups

910
00:43:35,030 --> 00:43:33,030
here and the work that's been done

911
00:43:37,700 --> 00:43:35,040
looking at organic inventory of these

912
00:43:41,360 --> 00:43:37,710
carbonaceous chondrites has shown a lot

913
00:43:43,310 --> 00:43:41,370

of variation among these subgroups

914
00:43:45,350 --> 00:43:43,320
and we don't really know where the icy

915
00:43:47,570 --> 00:43:45,360
bodies will necessarily said what type

916
00:43:49,160 --> 00:43:47,580
of chemistry is going on there there are

917
00:43:50,990 --> 00:43:49,170
similarities between all these subgroups

918
00:43:53,360 --> 00:43:51,000
but also some differences deadly

919
00:43:55,010 --> 00:43:53,370
questions lead to questions we do you

920
00:43:57,370 --> 00:43:55,020
think that the CI carbonaceous

921
00:44:00,080 --> 00:43:57,380
chondrites may be the most similar to

922
00:44:01,280 --> 00:44:00,090
icy bodies there the carbonaceous

923
00:44:04,370 --> 00:44:01,290
chondrites that have seen the most

924
00:44:06,170 --> 00:44:04,380
aqueous alteration liquid water present

925
00:44:07,760 --> 00:44:06,180
on the parent body so there's a

926
00:44:10,490 --> 00:44:07,770
suggestion that they may be related to

927
00:44:14,000 --> 00:44:10,500
comets and two other icy bodies and I'll

928
00:44:15,830 --> 00:44:14,010
show you a little bit about how that

929
00:44:19,820 --> 00:44:15,840
mainly just some differences in the

930
00:44:22,310 --> 00:44:19,830
organic compounds that are produced but

931
00:44:24,590 --> 00:44:22,320
just to start looking at some of the

932
00:44:26,210 --> 00:44:24,600
diversity that might exist this is

933
00:44:28,820 --> 00:44:26,220
looking at the merchants and meteorite

934
00:44:31,190 --> 00:44:28,830
which is a cm2 carbonaceous chondrite

935
00:44:32,780 --> 00:44:31,200
it's the carbonaceous chondrite that's

936
00:44:35,510 --> 00:44:32,790
been the most heavily studied for

937
00:44:38,810 --> 00:44:35,520
organics and what we find is a very wide

938
00:44:40,580 --> 00:44:38,820

diversity of organic compound a lot of

939
00:44:43,370 --> 00:44:40,590
insoluble organic matter is it's

940
00:44:45,170 --> 00:44:43,380
macromolecular material but also quite a

941
00:44:47,330 --> 00:44:45,180
number of different compound classes in

942
00:44:49,040 --> 00:44:47,340
the soluble organic matter and I've

943
00:44:51,620 --> 00:44:49,050
highlighted just a couple of compound

944
00:44:54,020 --> 00:44:51,630
classes they're irrelevant astrobiology

945
00:44:56,240 --> 00:44:54,030
roadmap to understanding the origin of

946
00:44:58,820 --> 00:44:56,250
the compounds relevant for the origin of

947
00:45:01,760 --> 00:44:58,830
life so things such as amino acids

948
00:45:03,650 --> 00:45:01,770
amines purines pyrimidines and heck

949
00:45:06,080 --> 00:45:03,660
nitrogen heterocycles things like that

950
00:45:08,480 --> 00:45:06,090
and we see that there are there's a

951
00:45:11,030 --> 00:45:08,490
large amount of these types of molecules

952
00:45:14,390 --> 00:45:11,040
there's a rich prebiotic chemistry going

953
00:45:16,670 --> 00:45:14,400
on here and in fact recent studies of

954
00:45:18,770 --> 00:45:16,680
the soluble material showed that there's

955
00:45:20,810 --> 00:45:18,780
likely millions of different structures

956
00:45:23,060 --> 00:45:20,820
of diverse structures of organic

957
00:45:25,280 --> 00:45:23,070
compounds in the merchants and meteorite

958
00:45:27,620 --> 00:45:25,290
and so when we learn from this if we're

959
00:45:30,080 --> 00:45:27,630
looking at the potential delivery of

960
00:45:32,000 --> 00:45:30,090
organics from primitive icy bodies that

961
00:45:34,970 --> 00:45:32,010
impacted the early Earth or other young

962
00:45:37,130 --> 00:45:34,980
planets is that a very large diversity

963
00:45:42,680 --> 00:45:37,140

of these compounds necessary for life

964
00:45:44,240 --> 00:45:42,690
could have been delivered and if we

965
00:45:47,510 --> 00:45:44,250
focus in a little bit on some of the

966
00:45:49,940 --> 00:45:47,520
molecules that we care about a lot for

967
00:45:50,430 --> 00:45:49,950
life on earth we can look at amino acids

968
00:45:52,890 --> 00:45:50,440
and it

969
00:45:54,750 --> 00:45:52,900
in clio basis animate alas as we know

970
00:45:56,609 --> 00:45:54,760
are the building blocks of proteins and

971
00:45:59,370 --> 00:45:56,619
enzymes and serve a lot of important

972
00:46:01,829 --> 00:45:59,380
roles in life on earth one of the

973
00:46:04,559 --> 00:46:01,839
mysteries or interesting factors about

974
00:46:06,980 --> 00:46:04,569
them is that amino acids are chiral that

975
00:46:09,510 --> 00:46:06,990
is amino acid molecules exist in two

976
00:46:12,930 --> 00:46:09,520
non-superimposable mirror image forms

977
00:46:15,089 --> 00:46:12,940
like your hands abiotic chemistry forms

978
00:46:16,710 --> 00:46:15,099
equal amounts of the two we get racemic

979
00:46:18,960 --> 00:46:16,720
mixture is equal amount to the left and

980
00:46:21,030 --> 00:46:18,970
right hand but life on Earth uses almost

981
00:46:23,819 --> 00:46:21,040
exclusively the left-handed form of

982
00:46:26,069 --> 00:46:23,829
these molecules and the way that life

983
00:46:27,870 --> 00:46:26,079
went but that chemistry went from

984
00:46:29,760 --> 00:46:27,880
producing the sequel mixtures to life

985
00:46:32,430 --> 00:46:29,770
using specifically the left-handed is a

986
00:46:34,559 --> 00:46:32,440
big question in astrobiology research

987
00:46:36,960 --> 00:46:34,569
and origin of life research what is the

988
00:46:39,059 --> 00:46:36,970

origin of that biological homo chirality

989
00:46:40,920 --> 00:46:39,069
and I'll show you in a minute what we

990
00:46:43,020 --> 00:46:40,930
might learn from meteorites about it and

991
00:46:45,960 --> 00:46:43,030
how that extrapolate to some of these

992
00:46:48,530 --> 00:46:45,970
icy bodies I also point out nucleobases

993
00:46:52,770 --> 00:46:48,540
because a range of nuclear bases and nut

994
00:46:54,780 --> 00:46:52,780
similar compounds have been shown I've

995
00:46:59,550 --> 00:46:54,790
been detected in carbonaceous chondrite

996
00:47:01,800 --> 00:46:59,560
you just went and I showed your a

997
00:47:04,800 --> 00:47:01,810
variety of compounds some of which like

998
00:47:08,339 --> 00:47:04,810
a demain and guanine are used in DNA and

999
00:47:10,050 --> 00:47:08,349
RNA I'm in life on earth but also some

1000
00:47:12,420 --> 00:47:10,060
alternate structures that are produced

1001
00:47:15,359 --> 00:47:12,430
by about a chemistry and show up in

1002
00:47:17,910 --> 00:47:15,369
these meteorites but aren't used much in

1003
00:47:19,740 --> 00:47:17,920
life and so that types of a final point

1004
00:47:22,380 --> 00:47:19,750
on that slide which is that there's

1005
00:47:25,410 --> 00:47:22,390
prebiotic chemistry that occurred on icy

1006
00:47:27,390 --> 00:47:25,420
bodies on rocky bodies can produce a

1007
00:47:29,700 --> 00:47:27,400
very large chemical diversity compared

1008
00:47:32,819 --> 00:47:29,710
to the specificity used in biology and

1009
00:47:35,150 --> 00:47:32,829
that's not own question of interest of

1010
00:47:37,260 --> 00:47:35,160
astrobiology roadmap I think does

1011
00:47:39,510 --> 00:47:37,270
understanding the diversity and the

1012
00:47:41,430 --> 00:47:39,520
distribution of these chemicals produced

1013
00:47:43,980 --> 00:47:41,440

in probiotic environments or on icy

1014
00:47:46,829 --> 00:47:43,990
bodies help us understand the origin of

1015
00:47:48,960 --> 00:47:46,839
the biological specificity why life uses

1016
00:47:52,319 --> 00:47:48,970
only the left-handed amino acids or

1017
00:47:53,670 --> 00:47:52,329
certain nuclear bases and this actually

1018
00:47:56,250 --> 00:47:53,680
came up a little bit in some of the

1019
00:47:58,350 --> 00:47:56,260
other roadmap webinars that have half

1020
00:48:00,510 --> 00:47:58,360
already particularly we had an earlier

1021
00:48:02,370 --> 00:48:00,520
one about sources of organic monomers

1022
00:48:06,120 --> 00:48:02,380
and some of these same questions were

1023
00:48:08,910 --> 00:48:06,130
released there we have two more slides I

1024
00:48:12,300 --> 00:48:08,920
think this one is just showing that

1025
00:48:13,950 --> 00:48:12,310
amino acid abundant varies across meteor

1026
00:48:18,240 --> 00:48:13,960
our class of us we have ten minutes left

1027
00:48:21,840 --> 00:48:18,250
so okay what I wanted to point out here

1028
00:48:24,510 --> 00:48:21,850
is that my pointer will go on the left

1029
00:48:27,210 --> 00:48:24,520
side here our meteorites that have been

1030
00:48:28,470 --> 00:48:27,220
extensively a curiously altered they

1031
00:48:30,570 --> 00:48:28,480
were exposed to a lot of liquid water

1032
00:48:32,790 --> 00:48:30,580
and their parent body let me go to about

1033
00:48:35,310 --> 00:48:32,800
here these meteorites have seen much

1034
00:48:37,170 --> 00:48:35,320
less water on their parent body and this

1035
00:48:39,390 --> 00:48:37,180
is a logarithmic scale of amino acid

1036
00:48:41,730 --> 00:48:39,400
abundant we see that the amino acid

1037
00:48:43,800 --> 00:48:41,740
abundance is quite sensitive to the

1038
00:48:48,900 --> 00:48:43,810

amount of aqueous alteration on the

1039
00:48:50,970 --> 00:48:48,910
parent body and I think that that gives

1040
00:48:52,980 --> 00:48:50,980
us something to look at as we start to

1041
00:48:54,720 --> 00:48:52,990
hopefully be able to examine organic

1042
00:48:58,260 --> 00:48:54,730
inventory and comments with future

1043
00:49:00,240 --> 00:48:58,270
comments sample return missions whether

1044
00:49:02,040 --> 00:49:00,250
these icy bodies where there's more

1045
00:49:04,170 --> 00:49:02,050
Equus alteration work potential for

1046
00:49:05,670 --> 00:49:04,180
liquid water interactions would affect

1047
00:49:09,900 --> 00:49:05,680
the abundance and distribution of

1048
00:49:13,500 --> 00:49:09,910
compounds that we see and the last point

1049
00:49:14,970 --> 00:49:13,510
I wanted to raise as a question that may

1050
00:49:17,610 --> 00:49:14,980
be of interest for the roadmap and

1051
00:49:21,180 --> 00:49:17,620
future research is going back that homo

1052
00:49:22,800 --> 00:49:21,190
chirality question abiotic chemistry

1053
00:49:25,140 --> 00:49:22,810
produces equal amounts of left and

1054
00:49:26,760 --> 00:49:25,150
right-handed most amino acids and most

1055
00:49:29,040 --> 00:49:26,770
meteorites that have been studied are

1056
00:49:33,120 --> 00:49:29,050
also racemic we see equal amounts to the

1057
00:49:35,460 --> 00:49:33,130
left and right but left-handed excesses

1058
00:49:38,370 --> 00:49:35,470
have been identified in some amino acids

1059
00:49:40,080 --> 00:49:38,380
in some meteorites and this plot began

1060
00:49:43,020 --> 00:49:40,090
is showing the correlation of those

1061
00:49:45,420 --> 00:49:43,030
excesses with aqueous alteration on the

1062
00:49:47,460 --> 00:49:45,430
parent body and again meteorites on the

1063
00:49:50,520 --> 00:49:47,470

left here these are just looking at the

1064
00:49:52,980 --> 00:49:50,530
percent of left-handed access in everest

1065
00:49:54,630 --> 00:49:52,990
amino acid i serve a lead in a variety

1066
00:49:57,150 --> 00:49:54,640
of meteorites the ones on the Left have

1067
00:49:59,100 --> 00:49:57,160
seen more aqueous alteration and also

1068
00:50:02,400 --> 00:49:59,110
show more of this left-handed excess and

1069
00:50:05,880 --> 00:50:02,410
so we wonder whether there are processes

1070
00:50:07,259 --> 00:50:05,890
on these icy bodies in these areas were

1071
00:50:09,329 --> 00:50:07,269
provided chemistry

1072
00:50:11,729 --> 00:50:09,339
been exposed to a grease alteration that

1073
00:50:13,919 --> 00:50:11,739
might have amplified in excess of

1074
00:50:15,389 --> 00:50:13,929
left-handed amino acids but then might

1075
00:50:17,759 --> 00:50:15,399
have been delivered to the early Earth

1076
00:50:20,149 --> 00:50:17,769
or to other planetary surfaces and in

1077
00:50:22,919 --> 00:50:20,159
some way helped to seed that origin of

1078
00:50:27,509 --> 00:50:22,929
biological homo chirality so this is a

1079
00:50:30,899 --> 00:50:27,519
question for for future research I see

1080
00:50:34,169 --> 00:50:30,909
Doug just asked about measuring Carol

1081
00:50:36,359 --> 00:50:34,179
accesses and comments I'm waiting for

1082
00:50:38,819 --> 00:50:36,369
Thomas sample return for that to happen

1083
00:50:40,679 --> 00:50:38,829
i think i'm not sure i don't know of any

1084
00:50:44,759 --> 00:50:40,689
way to be able to measure that remotely

1085
00:50:47,789 --> 00:50:44,769
the chiral accesses it's correct that

1086
00:50:50,549 --> 00:50:47,799
there's no tyrol measurement capability

1087
00:50:52,709 --> 00:50:50,559
and rosette correct yeah I'm pretty sure

1088
00:50:57,839 --> 00:50:52,719

the correct Aleta yes so we really need

1089
00:50:59,729 --> 00:50:57,849
either institue measurements and comets

1090
00:51:01,739 --> 00:50:59,739
which have a sort of chromatography that

1091
00:51:03,329 --> 00:51:01,749
can do chiro measurements or bringing

1092
00:51:05,880 --> 00:51:03,339
samples back and being able to do those

1093
00:51:07,409 --> 00:51:05,890
measurements here and I see penny asking

1094
00:51:09,929 --> 00:51:07,419
about destruction organics during entry

1095
00:51:12,359 --> 00:51:09,939
and impact on to the receiving target Oh

1096
00:51:15,929 --> 00:51:12,369
would I see materials be more or less

1097
00:51:18,120 --> 00:51:15,939
likely that's a good question that's not

1098
00:51:19,859 --> 00:51:18,130
what I've thought about much mike has

1099
00:51:22,499 --> 00:51:19,869
something to say about it yeah I would

1100
00:51:26,329 --> 00:51:22,509
like to comment on that you know the

1101
00:51:32,969 --> 00:51:26,339
real issue is the entry process its size

1102
00:51:34,829 --> 00:51:32,979
has benefits from breakup of the body if

1103
00:51:37,109 --> 00:51:34,839
you bring in a body that's a kilometer

1104
00:51:39,569 --> 00:51:37,119
diameter it pretty much is going to hit

1105
00:51:41,819 --> 00:51:39,579
the ground before it breaks up but when

1106
00:51:45,889 --> 00:51:41,829
you get to maybe a hundred meters or

1107
00:51:49,859 --> 00:51:45,899
less than the pressure wave which the

1108
00:51:53,309 --> 00:51:49,869
body encounters as the shock builds up

1109
00:51:57,209 --> 00:51:53,319
on entry will in fact cause a disruption

1110
00:52:00,209 --> 00:51:57,219
but it depends on the binding energy of

1111
00:52:02,789 --> 00:52:00,219
the material itself so for example a

1112
00:52:06,409 --> 00:52:02,799
rock like a meteorite that reaches the

1113
00:52:09,659 --> 00:52:06,419

ground may have a binding energy that's

1114
00:52:13,339 --> 00:52:09,669
something on the order of maybe 10,000

1115
00:52:15,210 --> 00:52:13,349
dynes per square centimeter whereas a

1116
00:52:17,940 --> 00:52:15,220
comet nucleus

1117
00:52:20,820 --> 00:52:17,950
a binding energy that is much much

1118
00:52:22,589 --> 00:52:20,830
smaller hundred times at least and so

1119
00:52:26,430 --> 00:52:22,599
the comet nucleus is going to actually

1120
00:52:29,640 --> 00:52:26,440
be broken up fairly easily and the

1121
00:52:32,790 --> 00:52:29,650
fragments will be decelerated quite

1122
00:52:34,830 --> 00:52:32,800
easily and they will essentially reach

1123
00:52:38,280 --> 00:52:34,840
the ground pretty much intact and

1124
00:52:40,500 --> 00:52:38,290
deliver their organics as they as they

1125
00:52:42,690 --> 00:52:40,510
do that the stone is like the

1126
00:52:45,420 --> 00:52:42,700
carbonaceous chondrites and so on and

1127
00:52:47,940 --> 00:52:45,430
merchants and so on those those bodies

1128
00:52:51,109 --> 00:52:47,950
reach the ground is pregnant sat at

1129
00:52:54,660 --> 00:52:51,119
range in size from elana meters

1130
00:52:56,820 --> 00:52:54,670
millimeters to meters and they also

1131
00:53:00,690 --> 00:52:56,830
deliver their materials to the ground

1132
00:53:03,599 --> 00:53:00,700
intact but it's the small particles that

1133
00:53:05,810 --> 00:53:03,609
are entering say own sizes on the order

1134
00:53:07,950 --> 00:53:05,820
of millimeters and so on like IDPs

1135
00:53:09,510 --> 00:53:07,960
basically are going to lose almost all

1136
00:53:12,990 --> 00:53:09,520
their organics because they get super

1137
00:53:15,089 --> 00:53:13,000
heated and even get vaporized and so on

1138
00:53:17,040 --> 00:53:15,099

it I said no we're running out of time

1139
00:53:19,740 --> 00:53:17,050
here I just want to say I noted that

1140
00:53:22,109 --> 00:53:19,750
down it has perhaps something against

1141
00:53:25,109 --> 00:53:22,119
you included in the road map document

1142
00:53:28,290 --> 00:53:25,119
that they're gonna think I'm noting some

1143
00:53:30,109 --> 00:53:28,300
of this down the document I will make

1144
00:53:31,950 --> 00:53:30,119
sure that that gets into the final

1145
00:53:34,260 --> 00:53:31,960
documented some vets to go to the

1146
00:53:36,540 --> 00:53:34,270
roadmap no these are very very valuable

1147
00:53:38,370 --> 00:53:36,550
college yeah it's the point of this is

1148
00:53:40,980 --> 00:53:38,380
to come up with the where we want to go

1149
00:53:42,859 --> 00:53:40,990
as research for the next ten years it's

1150
00:53:45,480 --> 00:53:42,869
very good to have these comments now

1151
00:53:47,579 --> 00:53:45,490
Andy Mike I suppose someone's going to

1152
00:53:51,480 --> 00:53:47,589
send us this list of comments is that

1153
00:53:54,420 --> 00:53:51,490
right it is you can never comments but

1154
00:53:56,160 --> 00:53:54,430
given that we are just coming to the top

1155
00:53:59,130 --> 00:53:56,170
of the hour I was going to take a moment

1156
00:54:01,290 --> 00:53:59,140
to to mention to people that the the

1157
00:54:04,650 --> 00:54:01,300
document that this presentation is based

1158
00:54:06,720 --> 00:54:04,660
on is now open for comments just in case

1159
00:54:08,460 --> 00:54:06,730
any of the people present or anyone

1160
00:54:11,070 --> 00:54:08,470
listening to this hasn't done that

1161
00:54:12,930 --> 00:54:11,080
before all you have to do is click on

1162
00:54:15,300 --> 00:54:12,940
the link and that will take you straight

1163
00:54:18,660 --> 00:54:15,310

to the Google document we do request

1164
00:54:21,390 --> 00:54:18,670
that if you have a google ID login with

1165
00:54:24,190 --> 00:54:21,400
them purely because it helps the authors

1166
00:54:25,900 --> 00:54:24,200
then see who's making which comment if

1167
00:54:29,050 --> 00:54:25,910
don't have a Google idea if you could

1168
00:54:32,530 --> 00:54:29,060
just note your name down on the comments

1169
00:54:35,200 --> 00:54:32,540
in case they need to get active and just

1170
00:54:38,200 --> 00:54:35,210
to be clear the overall process exactly

1171
00:54:40,180 --> 00:54:38,210
as we've been doing here is to note any

1172
00:54:43,030 --> 00:54:40,190
questions or ideas that could help

1173
00:54:45,130 --> 00:54:43,040
strengthen the paper because we are

1174
00:54:47,170 --> 00:54:45,140
coming to the end of the process we

1175
00:54:49,480 --> 00:54:47,180
still have a few weeks for people feel

1176
00:54:52,030 --> 00:54:49,490
to put their comments in but now would

1177
00:54:53,710 --> 00:54:52,040
be a great time to do it so we'd

1178
00:54:56,170 --> 00:54:53,720
encourage you to go back to the paper

1179
00:54:58,420 --> 00:54:56,180
insert any comments on there and yes

1180
00:55:02,349 --> 00:54:58,430
everything that's been entered into the

1181
00:55:05,170 --> 00:55:02,359
chat box will also be available now are

1182
00:55:07,180 --> 00:55:05,180
there any last questions or the

1183
00:55:09,579 --> 00:55:07,190
presenters need to to make any last

1184
00:55:11,910 --> 00:55:09,589
comments before we wrap it up this is

1185
00:55:16,120 --> 00:55:11,920
the last slide at my cabbage some

1186
00:55:18,760 --> 00:55:16,130
references there y plus we're going to

1187
00:55:21,220 --> 00:55:18,770
post a bibliography and so on and our

1188
00:55:23,740 --> 00:55:21,230

next to go around so I think that will

1189
00:55:28,109 --> 00:55:23,750
help people somewhat getting back into

1190
00:55:33,520 --> 00:55:30,609
excellent well in that case thank you

1191
00:55:36,250 --> 00:55:33,530
very much for a great presentation and

1192
00:55:38,260 --> 00:55:36,260
we hope to see everybody's comments

1193
00:55:40,680 --> 00:55:38,270
being popped in to the google document