



NASA
Astrobiology
Institute

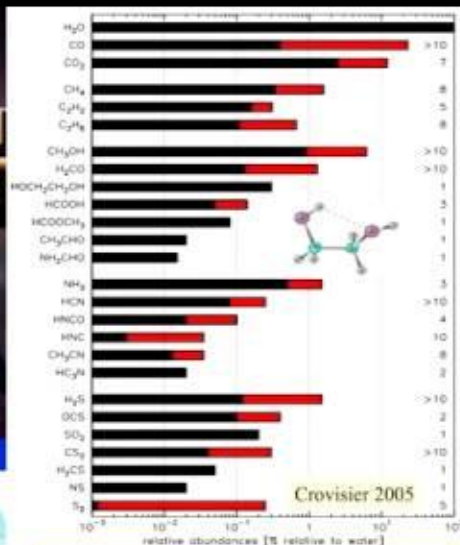
Team Overview Seminars
Goddard Space Flight Center



IRAM



Today



1
00:00:01,040 --> 00:00:05,110
good morning nai

2
00:00:08,870 --> 00:00:07,030
before i introduce

3
00:00:11,830 --> 00:00:08,880
our speaker today i want to make a

4
00:00:14,709 --> 00:00:11,840
couple of announcements one is that we

5
00:00:18,070 --> 00:00:14,719
were just notified yesterday that the

6
00:00:19,630 --> 00:00:18,080
nasa astrobiology program website

7
00:00:23,029 --> 00:00:19,640
at

8
00:00:26,230 --> 00:00:23,039
astrobiology.nasa.gov is one of 11 webby

9
00:00:27,990 --> 00:00:26,240
honorees this year in the category of

10
00:00:30,790 --> 00:00:28,000
science websites

11
00:00:32,950 --> 00:00:30,800
and we are in such good company uh as

12
00:00:36,310 --> 00:00:32,960
the california academy of sciences and

13
00:00:38,869 --> 00:00:36,320

technology review and seed magazine

14

00:00:43,590 --> 00:00:38,879

so we are really really thrilled this

15

00:00:45,990 --> 00:00:43,600

website was created by the i.t staff

16

00:00:48,150 --> 00:00:46,000

excuse me here at nai central

17

00:00:48,950 --> 00:00:48,160

and so we're really thrilled with all of

18

00:00:51,270 --> 00:00:48,960

this

19

00:00:53,750 --> 00:00:51,280

uh and if you haven't checked out the

20

00:00:55,510 --> 00:00:53,760

astrobiology program website i really

21

00:00:58,150 --> 00:00:55,520

encourage you to do so we put a lot of

22

00:00:59,830 --> 00:00:58,160

effort and love and energy into it uh

23

00:01:02,310 --> 00:00:59,840

and i think it's really a great resource

24

00:01:05,429 --> 00:01:02,320

astrobiology.nasa.gov

25

00:01:07,910 --> 00:01:05,439

and then it has links to nai to the exo

26

00:01:09,429 --> 00:01:07,920

program to a step in a stead and of

27

00:01:12,870 --> 00:01:09,439

course i'd particularly call your

28

00:01:14,630 --> 00:01:12,880

attention to the nai portion of the site

29

00:01:17,830 --> 00:01:14,640

but we're really really happy that the

30

00:01:19,030 --> 00:01:17,840

site provides access to information and

31

00:01:22,789 --> 00:01:19,040

the highlights

32

00:01:24,550 --> 00:01:22,799

of the entire astrobiology program

33

00:01:27,429 --> 00:01:24,560

the other thing i want to mention again

34

00:01:30,070 --> 00:01:27,439

i mentioned it at the monday seminar

35

00:01:32,390 --> 00:01:30,080

is that we have extended the deadline

36

00:01:35,510 --> 00:01:32,400

for applications from graduate students

37

00:01:38,710 --> 00:01:35,520

and postdocs to attend the annual summer

38

00:01:41,429 --> 00:01:38,720

school that we run in spain in a

39

00:01:44,069 --> 00:01:41,439

beautiful castle on the cantabrian coast

40

00:01:46,710 --> 00:01:44,079

uh with our spanish partner the centro

41

00:01:48,389 --> 00:01:46,720

de astro biologia so i encourage

42

00:01:50,710 --> 00:01:48,399

graduate students and postdocs who would

43

00:01:53,830 --> 00:01:50,720

be interested in participating to get

44

00:01:56,550 --> 00:01:53,840

applications in the application process

45

00:01:58,550 --> 00:01:56,560

is on our website and bruce

46

00:02:02,149 --> 00:01:58,560

is the person who's actually managing

47

00:02:04,469 --> 00:02:02,159

this for nai the topic this year is

48

00:02:07,350 --> 00:02:04,479

extremophiles and extraterrestrial

49

00:02:08,710 --> 00:02:07,360

habitability and the us speakers are

50

00:02:10,229 --> 00:02:08,720

going to be john barros from the

51
00:02:11,270 --> 00:02:10,239
university of washington and mike

52
00:02:13,830 --> 00:02:11,280
madigan

53
00:02:15,589 --> 00:02:13,840
from uh

54
00:02:17,270 --> 00:02:15,599
university of southern illinois at

55
00:02:19,830 --> 00:02:17,280
carbondale and you probably know that

56
00:02:22,390 --> 00:02:19,840
mike is the chief

57
00:02:26,150 --> 00:02:22,400
author editor now of the continuing

58
00:02:27,750 --> 00:02:26,160
series of brock microbiology

59
00:02:29,270 --> 00:02:27,760
the european speakers are going to

60
00:02:30,949 --> 00:02:29,280
include ricardo emiles and david

61
00:02:33,110 --> 00:02:30,959
gulicinski so i think it's going to be

62
00:02:34,229 --> 00:02:33,120
a really really good week and we'd like

63
00:02:36,710 --> 00:02:34,239

to see a

64

00:02:37,670 --> 00:02:36,720

really robust set of applicants

65

00:02:40,309 --> 00:02:37,680

okay

66

00:02:42,150 --> 00:02:40,319

so uh without further ado i would like

67

00:02:44,309 --> 00:02:42,160

to introduce somebody who needs no

68

00:02:46,869 --> 00:02:44,319

introduction in this community but i'll

69

00:02:49,670 --> 00:02:46,879

introduce them anyway uh that's dr mike

70

00:02:51,430 --> 00:02:49,680

mumma the pi of the goddard space flight

71

00:02:53,509 --> 00:02:51,440

center team

72

00:02:55,110 --> 00:02:53,519

mike got his bachelor's in physics from

73

00:02:56,949 --> 00:02:55,120

franklin and marshall college and his

74

00:02:58,150 --> 00:02:56,959

phd in physics from the university of

75

00:03:01,030 --> 00:02:58,160

pittsburgh

76
00:03:01,910 --> 00:03:01,040
and he has been at goddard space flight

77
00:03:04,149 --> 00:03:01,920
center

78
00:03:07,110 --> 00:03:04,159
for most of his career but i see there

79
00:03:07,990 --> 00:03:07,120
is an affiliation with penn state in

80
00:03:09,750 --> 00:03:08,000
there

81
00:03:11,990 --> 00:03:09,760
so uh mike that was something i didn't

82
00:03:14,869 --> 00:03:12,000
know about you and uh without further

83
00:03:17,350 --> 00:03:14,879
ado i will turn it over to you

84
00:03:19,509 --> 00:03:17,360
thanks very much carl uh let me get

85
00:03:21,190 --> 00:03:19,519
right on first of all uh for those of

86
00:03:23,270 --> 00:03:21,200
you who haven't finished your income tax

87
00:03:24,869 --> 00:03:23,280
return you have three hours or whatever

88
00:03:26,869 --> 00:03:24,879

i guess until midnight

89

00:03:29,430 --> 00:03:26,879

so i'll try to keep this seminar to no

90

00:03:31,589 --> 00:03:29,440

more than 50 minutes in honor of that

91

00:03:33,830 --> 00:03:31,599

obligation

92

00:03:36,390 --> 00:03:33,840

okay so uh first of all let's get right

93

00:03:39,270 --> 00:03:36,400

on to it a few general overview slides

94

00:03:41,110 --> 00:03:39,280

this is what we're all after in the ni

95

00:03:43,190 --> 00:03:41,120

it's not a trivial question regarding

96

00:03:45,110 --> 00:03:43,200

the delivery of water to earth

97

00:03:46,869 --> 00:03:45,120

because as you know the the earth as we

98

00:03:50,229 --> 00:03:46,879

know it today is the product of a

99

00:03:52,149 --> 00:03:50,239

collision with a mars-sized proto-planet

100

00:03:54,149 --> 00:03:52,159

somewhere on the order of 50 to 100

101
00:03:55,190 --> 00:03:54,159
million years after the proto-earth was

102
00:03:57,030 --> 00:03:55,200
formed

103
00:03:58,470 --> 00:03:57,040
the debris accumulated the earth moon

104
00:04:00,070 --> 00:03:58,480
system and

105
00:04:02,550 --> 00:04:00,080
the earth at that time was covered by a

106
00:04:04,470 --> 00:04:02,560
magma ocean which would of course uh

107
00:04:05,990 --> 00:04:04,480
have lost whatever primordial atmosphere

108
00:04:07,030 --> 00:04:06,000
and oceans it might have been endowed

109
00:04:09,270 --> 00:04:07,040
with

110
00:04:11,110 --> 00:04:09,280
uh and so a new one had to be delivered

111
00:04:13,750 --> 00:04:11,120
now whether some of that came from

112
00:04:14,390 --> 00:04:13,760
inside the earth to continue outgassing

113
00:04:15,750 --> 00:04:14,400

or

114

00:04:17,749 --> 00:04:15,760

most of it came

115

00:04:20,390 --> 00:04:17,759

by exogenous delivery is one of the key

116

00:04:22,870 --> 00:04:20,400

issues that we're interested in and

117

00:04:25,830 --> 00:04:22,880

along with that water came a rich array

118

00:04:30,150 --> 00:04:25,840

of organics prebiotic organics uh which

119

00:04:32,310 --> 00:04:30,160

is one of the key key themes of our team

120

00:04:34,950 --> 00:04:32,320

really what we do starts with the

121

00:04:36,550 --> 00:04:34,960

overall cycle of material

122

00:04:39,749 --> 00:04:36,560

beginning with

123

00:04:42,230 --> 00:04:39,759

the diffuse interstellar medium going on

124

00:04:44,230 --> 00:04:42,240

towards the collapse of accumulation

125

00:04:45,350 --> 00:04:44,240

collapse of dense interstellar dust

126
00:04:47,670 --> 00:04:45,360
clouds

127
00:04:49,510 --> 00:04:47,680
which are rich in molecular chemistry

128
00:04:51,590 --> 00:04:49,520
and also in

129
00:04:53,189 --> 00:04:51,600
dust grains themselves

130
00:04:55,510 --> 00:04:53,199
the formation of young stars and

131
00:04:56,469 --> 00:04:55,520
planetary systems from those treating

132
00:04:58,390 --> 00:04:56,479
grains

133
00:04:59,990 --> 00:04:58,400
uh and then on towards

134
00:05:02,469 --> 00:05:00,000
all planets

135
00:05:05,189 --> 00:05:02,479
of course our solar system

136
00:05:05,990 --> 00:05:05,199
is the paradigm for the others

137
00:05:08,310 --> 00:05:06,000
uh

138
00:05:10,070 --> 00:05:08,320

we're interested in first the processes

139

00:05:12,230 --> 00:05:10,080

that affect ices and dust and

140

00:05:13,430 --> 00:05:12,240

protoplanetary disks there's this little

141

00:05:16,150 --> 00:05:13,440

cartoon

142

00:05:20,150 --> 00:05:16,160

sketches a disc in cross section

143

00:05:23,830 --> 00:05:21,830

various processes that affect the

144

00:05:26,070 --> 00:05:23,840

chemistry are indicated here i should

145

00:05:27,990 --> 00:05:26,080

comment that in recent years x-ray

146

00:05:29,430 --> 00:05:28,000

processing has emerged as a very

147

00:05:30,790 --> 00:05:29,440

important

148

00:05:32,469 --> 00:05:30,800

new

149

00:05:34,070 --> 00:05:32,479

mechanism for

150

00:05:36,310 --> 00:05:34,080

producing uh

151
00:05:39,029 --> 00:05:36,320
ion molecule chemistry in regions that

152
00:05:40,710 --> 00:05:39,039
uv cannot well penetrate

153
00:05:43,029 --> 00:05:40,720
and so this has become very uh very

154
00:05:44,629 --> 00:05:43,039
important understanding the gradients in

155
00:05:46,310 --> 00:05:44,639
chemistry and so on

156
00:05:48,950 --> 00:05:46,320
both with distance above the mid plane

157
00:05:50,070 --> 00:05:48,960
and also with distant from the young sun

158
00:05:52,070 --> 00:05:50,080
of course there's a good deal of

159
00:05:54,230 --> 00:05:52,080
accumulation going on as these discs

160
00:05:56,390 --> 00:05:54,240
evolve and ultimately

161
00:05:59,510 --> 00:05:56,400
much of that material is delivered to

162
00:06:01,510 --> 00:05:59,520
the earth and other terrestrial planets

163
00:06:04,629 --> 00:06:01,520

in the form of

164

00:06:07,749 --> 00:06:04,639

meteorites asteroid fragments and even

165

00:06:09,510 --> 00:06:07,759

the nuclei of comets or comet dust

166

00:06:11,189 --> 00:06:09,520

uh so this is another

167

00:06:13,430 --> 00:06:11,199

thing

168

00:06:15,590 --> 00:06:13,440

about that in a minute

169

00:06:17,670 --> 00:06:15,600

and finally one of the issues uh that

170

00:06:20,309 --> 00:06:17,680

helps us to distinguish

171

00:06:23,189 --> 00:06:20,319

uh what the gradient of organic

172

00:06:24,710 --> 00:06:23,199

chemistry really was in material in our

173

00:06:26,710 --> 00:06:24,720

early early

174

00:06:29,990 --> 00:06:26,720

early phase of our solar system

175

00:06:31,909 --> 00:06:30,000

is the actual uh isotopic ratio there's

176

00:06:34,870 --> 00:06:31,919

a topologies of water

177

00:06:37,510 --> 00:06:34,880

uh in particular in the icy bodies or a

178

00:06:39,350 --> 00:06:37,520

molecular hydrogen in the gas giants

179

00:06:41,670 --> 00:06:39,360

as a function of distance from the young

180

00:06:44,070 --> 00:06:41,680

sun we think that near the

181

00:06:46,550 --> 00:06:44,080

in the terrestrial planets region uh

182

00:06:48,629 --> 00:06:46,560

water that was formed there and react in

183

00:06:50,629 --> 00:06:48,639

the gas phase should have very low doh

184

00:06:51,909 --> 00:06:50,639

probably in equilibrium with nebular

185

00:06:54,150 --> 00:06:51,919

hydrogen

186

00:06:55,749 --> 00:06:54,160

uh or about uh eight times smaller than

187

00:06:58,469 --> 00:06:55,759

terrestrial oceans

188

00:07:00,150 --> 00:06:58,479

uh and then uh water that was a legacy

189

00:07:02,790 --> 00:07:00,160

ice from the interstellar cloud core

190

00:07:04,390 --> 00:07:02,800

should have a much higher uh deuterium

191

00:07:05,990 --> 00:07:04,400

content probably a factor of two or

192

00:07:07,909 --> 00:07:06,000

three times higher than that in earth's

193

00:07:11,029 --> 00:07:07,919

oceans today

194

00:07:13,510 --> 00:07:11,039

so all these are keys that we're uh

195

00:07:15,670 --> 00:07:13,520

following and trying to get some clues

196

00:07:17,510 --> 00:07:15,680

into what really happened of course this

197

00:07:19,270 --> 00:07:17,520

will take at least two more renewals in

198

00:07:21,189 --> 00:07:19,280

the nai before we'll have definitive

199

00:07:24,070 --> 00:07:21,199

answers

200

00:07:26,790 --> 00:07:24,080

so uh these uh were divided essentially

201
00:07:29,350 --> 00:07:26,800
into three uh scientific themes

202
00:07:31,830 --> 00:07:29,360
uh and i'm actually gonna uh introduce

203
00:07:33,749 --> 00:07:31,840
theme two first which is uh the first

204
00:07:35,589 --> 00:07:33,759
phase that

205
00:07:37,749 --> 00:07:35,599
happens namely the

206
00:07:40,870 --> 00:07:37,759
material in

207
00:07:42,469 --> 00:07:40,880
dense cloud cores and uh discs

208
00:07:44,550 --> 00:07:42,479
and then go on from there to

209
00:07:47,430 --> 00:07:44,560
understanding the uh

210
00:07:49,830 --> 00:07:47,440
the truths that we can sample in terms

211
00:07:53,270 --> 00:07:49,840
of commentary bodies um meteoro

212
00:07:55,430 --> 00:07:53,280
meteorites and lunar uh rushes

213
00:07:57,430 --> 00:07:55,440

and then finally uh end up with theme

214

00:07:59,350 --> 00:07:57,440

four which is uh

215

00:08:01,589 --> 00:07:59,360

i'm sorry theme three is the laboratory

216

00:08:03,430 --> 00:08:01,599

processing of astrophysical lice analogs

217

00:08:04,309 --> 00:08:03,440

and so on for comparing the chemistry on

218

00:08:06,469 --> 00:08:04,319

them

219

00:08:10,150 --> 00:08:06,479

uh to clarify processes that actually

220

00:08:13,830 --> 00:08:12,070

moderating the chemistry of ices on the

221

00:08:16,950 --> 00:08:13,840

way from the interstellar

222

00:08:19,589 --> 00:08:16,960

dense cloud core to the cometary bodies

223

00:08:21,749 --> 00:08:19,599

and finally wrap up with some discussion

224

00:08:23,270 --> 00:08:21,759

of advanced

225

00:08:25,189 --> 00:08:23,280

methodologies being developed for

226

00:08:27,670 --> 00:08:25,199

in-situ analysis

227

00:08:29,589 --> 00:08:27,680

of complex organic organics in the solar

228

00:08:32,230 --> 00:08:29,599

system

229

00:08:35,269 --> 00:08:32,240

now this is a uh a bit

230

00:08:37,670 --> 00:08:35,279

of a revised map of our

231

00:08:39,589 --> 00:08:37,680

the co-investigators in topical areas

232

00:08:40,790 --> 00:08:39,599

before i had organized this according to

233

00:08:42,949 --> 00:08:40,800

institution

234

00:08:44,630 --> 00:08:42,959

but it makes far more sense to do so by

235

00:08:47,269 --> 00:08:44,640

the topical area

236

00:08:49,750 --> 00:08:47,279

beginning at the top left we go around

237

00:08:52,310 --> 00:08:49,760

in a clockwise sense essentially

238

00:08:54,790 --> 00:08:52,320

uh we'll talk first about the ism the

239

00:08:56,870 --> 00:08:54,800

nato cloud core discs in blue are the

240

00:08:59,430 --> 00:08:56,880

names of the co-eyes who are at

241

00:09:00,550 --> 00:08:59,440

universities in the red uh are all at

242

00:09:02,949 --> 00:09:00,560

goddard

243

00:09:05,350 --> 00:09:02,959

um but you'll notice uh as you go along

244

00:09:07,910 --> 00:09:05,360

here we've got uh

245

00:09:10,150 --> 00:09:07,920

work on dynamical sculpting uh hal

246

00:09:11,509 --> 00:09:10,160

levison sweary is one of the presenters

247

00:09:14,070 --> 00:09:11,519

of the niece model

248

00:09:16,310 --> 00:09:14,080

commentary composition is heavily uh

249

00:09:18,790 --> 00:09:16,320

centered here in maryland with a little

250

00:09:21,590 --> 00:09:18,800

compliment from bill ervine

251
00:09:23,670 --> 00:09:21,600
at umass he gets us into the

252
00:09:25,750 --> 00:09:23,680
large millimeter telescope in mexico and

253
00:09:27,509 --> 00:09:25,760
that becomes fully operational

254
00:09:29,990 --> 00:09:27,519
and so on

255
00:09:31,910 --> 00:09:30,000
uh lab work meteoritics and natural

256
00:09:34,790 --> 00:09:31,920
samples as we call them is under the

257
00:09:37,030 --> 00:09:34,800
direction of jason dworkin in his lab

258
00:09:39,190 --> 00:09:37,040
lunar samples with rich walker and so

259
00:09:41,829 --> 00:09:39,200
forth cosmic ice lab with marla moore

260
00:09:43,829 --> 00:09:41,839
reggie hudson dust lab mars biomarkers

261
00:09:45,590 --> 00:09:43,839
exoplanets and finally

262
00:09:46,870 --> 00:09:45,600
onto instrumental techniques and then

263
00:09:48,150 --> 00:09:46,880

wrapping it all

264

00:09:50,150 --> 00:09:48,160

together and

265

00:09:51,590 --> 00:09:50,160

and representing us to the outside world

266

00:09:55,190 --> 00:09:51,600

as our epo

267

00:09:57,030 --> 00:09:55,200

lead who is uh cynthia chung a phd uh

268

00:09:58,790 --> 00:09:57,040

scientist

269

00:10:00,550 --> 00:09:58,800

so i'll uh just uh

270

00:10:03,350 --> 00:10:00,560

mention a few highlights uh in this

271

00:10:05,190 --> 00:10:03,360

overview uh it is my intent not to

272

00:10:08,389 --> 00:10:05,200

overwhelm people who are not in the

273

00:10:09,590 --> 00:10:08,399

specific uh fields that our team works

274

00:10:13,190 --> 00:10:09,600

but uh

275

00:10:15,110 --> 00:10:13,200

uh to present to you just a uh a glimpse

276

00:10:16,310 --> 00:10:15,120
of what's going on with hopefully

277

00:10:19,670 --> 00:10:16,320
something you can

278

00:10:21,509 --> 00:10:19,680
grasp and appreciate and uh perhaps even

279

00:10:22,949 --> 00:10:21,519
uh become involved in later on so

280

00:10:24,550 --> 00:10:22,959
interested

281

00:10:25,750 --> 00:10:24,560
so first let's look at some of the

282

00:10:27,670 --> 00:10:25,760
things we're doing in the way of

283

00:10:30,470 --> 00:10:27,680
interstellar molecules

284

00:10:32,389 --> 00:10:30,480
uh this is work being done and led by

285

00:10:33,829 --> 00:10:32,399
jeff blake at cal tech

286

00:10:35,110 --> 00:10:33,839
who's been a member of our team since

287

00:10:37,990 --> 00:10:35,120
the beginning

288

00:10:39,910 --> 00:10:38,000

uh abbey mandel uh is working uh

289

00:10:42,230 --> 00:10:39,920

intensely with jeff and we're also tied

290

00:10:43,590 --> 00:10:42,240

in with avina vendashoka uh and her

291

00:10:46,790 --> 00:10:43,600

collaborators

292

00:10:48,949 --> 00:10:46,800

clasp on topic don and so on we use uh

293

00:10:51,030 --> 00:10:48,959

jeff uses uh spitzer and keck and we're

294

00:10:53,670 --> 00:10:51,040

now using uh ground-based well he's been

295

00:10:55,350 --> 00:10:53,680

using nurse pack at keck for a long time

296

00:10:57,350 --> 00:10:55,360

and also uh

297

00:10:59,190 --> 00:10:57,360

using the vlt a high resolution

298

00:11:02,150 --> 00:10:59,200

spectrometer

299

00:11:04,230 --> 00:11:02,160

at the very large telescope called the

300

00:11:06,230 --> 00:11:04,240

spectrometer is called crirez

301
00:11:08,069 --> 00:11:06,240
so on the top left here you just see a

302
00:11:10,470 --> 00:11:08,079
typical spectrum this is in the 14

303
00:11:13,430 --> 00:11:10,480
micron spectral range of acetylene

304
00:11:15,350 --> 00:11:13,440
hydrogen cyanide and co2

305
00:11:17,670 --> 00:11:15,360
in the disc around the young star

306
00:11:19,750 --> 00:11:17,680
and from this you can obtain a lot of

307
00:11:22,069 --> 00:11:19,760
information about the physics of the

308
00:11:24,550 --> 00:11:22,079
medium the chemistry of the media and so

309
00:11:26,069 --> 00:11:24,560
forth and so on

310
00:11:28,150 --> 00:11:26,079
uh here's an example of some of the work

311
00:11:30,310 --> 00:11:28,160
being done on the ground and the

312
00:11:32,310 --> 00:11:30,320
takeaway message here is that from the

313
00:11:33,910 --> 00:11:32,320

ground you can actually detect water

314

00:11:36,389 --> 00:11:33,920

vapor

315

00:11:38,550 --> 00:11:36,399

at a relatively high temperature 800

316

00:11:40,710 --> 00:11:38,560

kelvin in the disks

317

00:11:42,389 --> 00:11:40,720

near these young stars

318

00:11:44,870 --> 00:11:42,399

this particularly happens to be a low

319

00:11:47,670 --> 00:11:44,880

mass star relatively young than the

320

00:11:49,430 --> 00:11:47,680

first million years of its life but uh

321

00:11:50,870 --> 00:11:49,440

this way you could really uh see an

322

00:11:51,910 --> 00:11:50,880

awful lot of

323

00:11:53,190 --> 00:11:51,920

uh

324

00:11:55,269 --> 00:11:53,200

material

325

00:11:56,630 --> 00:11:55,279

uh and the chemistry of physics that's

326
00:11:58,470 --> 00:11:56,640
going on

327
00:12:00,630 --> 00:11:58,480
now there's an issue as to how far one

328
00:12:01,750 --> 00:12:00,640
can push this from the ground

329
00:12:04,470 --> 00:12:01,760
and we know

330
00:12:07,750 --> 00:12:04,480
that we'll ultimately need a space

331
00:12:08,870 --> 00:12:07,760
observatory to do this in its fullest

332
00:12:10,949 --> 00:12:08,880
fruition

333
00:12:14,150 --> 00:12:10,959
but uh here you can see uh that on the

334
00:12:16,949 --> 00:12:14,160
lower right uh avi's extraction avi

335
00:12:18,470 --> 00:12:16,959
mandel's extraction of uh the o h

336
00:12:21,509 --> 00:12:18,480
emission uh

337
00:12:22,470 --> 00:12:21,519
from a the disc around a uh per big a b

338
00:12:24,629 --> 00:12:22,480

star

339

00:12:28,150 --> 00:12:24,639

is shown he's actually pioneered a way

340

00:12:29,750 --> 00:12:28,160

of uh extracting these weak emission

341

00:12:32,069 --> 00:12:29,760

signals in the presence of the strong

342

00:12:33,829 --> 00:12:32,079

stellar continuum and is getting signal

343

00:12:36,310 --> 00:12:33,839

to noise ratios on the order of two

344

00:12:37,910 --> 00:12:36,320

thousand to one on the stellar continuum

345

00:12:40,230 --> 00:12:37,920

and this is actually i think the best

346

00:12:42,710 --> 00:12:40,240

that uh has been done so far

347

00:12:44,629 --> 00:12:42,720

uh using uh nurse beckett keck or deed

348

00:12:46,470 --> 00:12:44,639

from any ground-based system

349

00:12:48,470 --> 00:12:46,480

so this is actually

350

00:12:50,069 --> 00:12:48,480

going on now towards searches for

351

00:12:52,470 --> 00:12:50,079

methane and other more interesting

352

00:12:55,910 --> 00:12:52,480

organic molecules than just oh

353

00:12:58,150 --> 00:12:55,920

but you can see where this is going

354

00:13:00,310 --> 00:12:58,160

i'll skip this one

355

00:13:03,110 --> 00:13:00,320

going on towards another element of our

356

00:13:06,310 --> 00:13:03,120

team uh we have carol grady mark

357

00:13:09,110 --> 00:13:06,320

kutchner and aki roberts who are another

358

00:13:11,430 --> 00:13:09,120

organizational unit here at goddard uh

359

00:13:13,430 --> 00:13:11,440

and they are working on discs around

360

00:13:14,470 --> 00:13:13,440

young stars carol grady has been doing

361

00:13:16,790 --> 00:13:14,480

this for

362

00:13:17,910 --> 00:13:16,800

two decades now and is well known in the

363

00:13:20,790 --> 00:13:17,920

field

364

00:13:23,509 --> 00:13:20,800

mark and aki are working on discs and

365

00:13:25,750 --> 00:13:23,519

also on exoplanet detections

366

00:13:27,590 --> 00:13:25,760

and uh we have a large number of

367

00:13:28,629 --> 00:13:27,600

missions within which we're involved you

368

00:13:31,430 --> 00:13:28,639

can see uh

369

00:13:34,470 --> 00:13:31,440

on the left of this slide of a uh

370

00:13:37,110 --> 00:13:34,480

five well actually four missions uh webb

371

00:13:38,629 --> 00:13:37,120

telescope in the uh top left

372

00:13:40,949 --> 00:13:38,639

epoxy mission which you'll hear more

373

00:13:41,990 --> 00:13:40,959

about uh was once called deep impact and

374

00:13:44,550 --> 00:13:42,000

is now

375

00:13:45,910 --> 00:13:44,560

uh looking at exo earth as an exoplanet

376

00:13:47,269 --> 00:13:45,920

we'll hear about more about that a

377

00:13:50,470 --> 00:13:47,279

little later

378

00:13:52,470 --> 00:13:50,480

a new concept being developed to image

379

00:13:54,470 --> 00:13:52,480

worlds around other stars this is called

380

00:13:57,030 --> 00:13:54,480

the new worlds observer part of the tpf

381

00:13:59,509 --> 00:13:57,040

program that we're involved in

382

00:14:02,310 --> 00:13:59,519

through mark and aki

383

00:14:04,629 --> 00:14:02,320

an interferometric program uh to map

384

00:14:05,910 --> 00:14:04,639

these uh regions at high angular

385

00:14:07,590 --> 00:14:05,920

resolution

386

00:14:10,310 --> 00:14:07,600

and then various theoretical studies

387

00:14:11,990 --> 00:14:10,320

this happens to be a model of a disk uh

388

00:14:14,230 --> 00:14:12,000

the influence of an earth mass planet

389

00:14:16,629 --> 00:14:14,240

around a nearby star

390

00:14:18,790 --> 00:14:16,639

which mark has developed we won't have

391

00:14:20,870 --> 00:14:18,800

time nor the internet bandwidth to show

392

00:14:23,430 --> 00:14:20,880

you the uh movie of that

393

00:14:24,949 --> 00:14:23,440

uh but uh we'll make that available if

394

00:14:27,030 --> 00:14:24,959

you're so interested

395

00:14:28,790 --> 00:14:27,040

and there's some contact uh points over

396

00:14:31,430 --> 00:14:28,800

here you you'll get this when you see

397

00:14:32,949 --> 00:14:31,440

the posted pdf file or go up in a couple

398

00:14:35,509 --> 00:14:32,959

of days you can write all this stuff

399

00:14:37,030 --> 00:14:35,519

down or look at it again

400

00:14:39,269 --> 00:14:37,040

so here are a couple of things are going

401
00:14:41,269 --> 00:14:39,279
on here's a particular deep debris disc

402
00:14:44,230 --> 00:14:41,279
around the young star seen edge on up

403
00:14:46,710 --> 00:14:44,240
the upper right and by looking at the

404
00:14:48,310 --> 00:14:46,720
morphology of the disc and its energy

405
00:14:50,310 --> 00:14:48,320
budget and so forth you can learn a good

406
00:14:53,110 --> 00:14:50,320
deal about how dust and debris are

407
00:14:54,629 --> 00:14:53,120
distributed about that young star

408
00:14:57,189 --> 00:14:54,639
likely they're made by the comet

409
00:14:59,509 --> 00:14:57,199
asteroid collisions and evaporation and

410
00:15:01,350 --> 00:14:59,519
so forth and aki's been studying this

411
00:15:02,389 --> 00:15:01,360
since her thesis days looking at beta

412
00:15:07,350 --> 00:15:02,399
pic

413
00:15:08,629 --> 00:15:07,360

abundance elemental abundance ratios and

414

00:15:11,189 --> 00:15:08,639

so forth

415

00:15:13,189 --> 00:15:11,199

and we'll post a few papers along with

416

00:15:14,949 --> 00:15:13,199

our powerpoint presentation so those who

417

00:15:18,150 --> 00:15:14,959

are interested can in fact get into this

418

00:15:19,910 --> 00:15:18,160

in a little better little greater depth

419

00:15:22,470 --> 00:15:19,920

uh we're leading in this team is leading

420

00:15:23,990 --> 00:15:22,480

on towards the herschel uh launch this

421

00:15:26,389 --> 00:15:24,000

year

422

00:15:29,110 --> 00:15:26,399

which is scheduled for may 6th uh

423

00:15:31,430 --> 00:15:29,120

they are in fact involved in the

424

00:15:32,949 --> 00:15:31,440

so-called gasp project this is a guest

425

00:15:37,030 --> 00:15:32,959

in protoplanetary

426
00:15:38,870 --> 00:15:37,040
systems uh there's a plan to observe 250

427
00:15:41,509 --> 00:15:38,880
young stellar systems

428
00:15:43,910 --> 00:15:41,519
and this will in fact expand the uh

429
00:15:46,150 --> 00:15:43,920
current database acquired by uh

430
00:15:47,750 --> 00:15:46,160
another part of our team jeff blake and

431
00:15:49,829 --> 00:15:47,760
avina vandashok

432
00:15:51,910 --> 00:15:49,839
we've observed about 100 young stellar

433
00:15:54,150 --> 00:15:51,920
systems using high resolution infrared

434
00:15:56,949 --> 00:15:54,160
from the ground

435
00:15:58,949 --> 00:15:56,959
so this is these are the classes of

436
00:16:01,670 --> 00:15:58,959
information that one learns from this

437
00:16:03,670 --> 00:16:01,680
kind of study

438
00:16:05,910 --> 00:16:03,680

okay well then of course the key issue

439

00:16:07,990 --> 00:16:05,920

uh once you know the that planets can

440

00:16:09,430 --> 00:16:08,000

form in these disks or that the they do

441

00:16:12,230 --> 00:16:09,440

in fact uh

442

00:16:14,710 --> 00:16:12,240

exist uh is to actually characterize

443

00:16:17,829 --> 00:16:14,720

their nature frank deming is leading

444

00:16:19,189 --> 00:16:17,839

that work for our team and also and

445

00:16:21,110 --> 00:16:19,199

through independent

446

00:16:23,829 --> 00:16:21,120

funding he's actually one of the key

447

00:16:24,870 --> 00:16:23,839

leaders in the world in this field

448

00:16:27,269 --> 00:16:24,880

uh

449

00:16:30,150 --> 00:16:27,279

one of the focus foci that he's

450

00:16:32,710 --> 00:16:30,160

pursuing at the moment is to

451
00:16:34,790 --> 00:16:32,720
look at super earth's orbiting m dwarfs

452
00:16:36,629 --> 00:16:34,800
this was actually published

453
00:16:38,389 --> 00:16:36,639
the idea was published

454
00:16:39,990 --> 00:16:38,399
in nature

455
00:16:42,629 --> 00:16:40,000
late last year

456
00:16:44,389 --> 00:16:42,639
uh and we followed up with uh webb this

457
00:16:47,110 --> 00:16:44,399
web telescope

458
00:16:50,470 --> 00:16:47,120
to search for uh carbon dioxide in the

459
00:16:52,230 --> 00:16:50,480
4.3 micron region this dip right here

460
00:16:55,269 --> 00:16:52,240
showing that measured at low resolution

461
00:16:57,910 --> 00:16:55,279
against the background continuum uh of

462
00:17:00,230 --> 00:16:57,920
the planet and this is in fact the would

463
00:17:02,550 --> 00:17:00,240

be the signature of co2

464

00:17:05,669 --> 00:17:02,560

for a uh

465

00:17:07,590 --> 00:17:05,679

object that's at 22 parsecs distance and

466

00:17:08,549 --> 00:17:07,600

has a temperature of 300 kelvin and so

467

00:17:10,470 --> 00:17:08,559

on

468

00:17:14,630 --> 00:17:10,480

so this does look feasible and this is

469

00:17:18,710 --> 00:17:17,350

the second class of investigation he's

470

00:17:20,069 --> 00:17:18,720

pursuing his

471

00:17:22,069 --> 00:17:20,079

characterization of earth as an

472

00:17:23,990 --> 00:17:22,079

exoplanet and this is being done with

473

00:17:25,829 --> 00:17:24,000

the epoxy spacecraft which is in an

474

00:17:28,789 --> 00:17:25,839

extended mission phase

475

00:17:29,750 --> 00:17:28,799

after its successful targeted uh impact

476
00:17:32,390 --> 00:17:29,760
of the

477
00:17:34,390 --> 00:17:32,400
projectile on the temple one nucleus of

478
00:17:37,029 --> 00:17:34,400
temple comet temple one

479
00:17:39,350 --> 00:17:37,039
in 2005.

480
00:17:40,950 --> 00:17:39,360
uh so they've already uh you've heard

481
00:17:42,789 --> 00:17:40,960
about this on monday

482
00:17:44,830 --> 00:17:42,799
through when vicki meadows gave her

483
00:17:48,310 --> 00:17:44,840
synopsis of everything going on in the

484
00:17:50,789 --> 00:17:48,320
dpl but essentially what's been done now

485
00:17:53,110 --> 00:17:50,799
is to demonstrate that looking at the

486
00:17:54,549 --> 00:17:53,120
earth as an exoplanet as a single pixel

487
00:17:57,350 --> 00:17:54,559
basically

488
00:17:59,430 --> 00:17:57,360

uh it is possible to separate or

489

00:18:00,870 --> 00:17:59,440

identify that there are oceans and

490

00:18:03,430 --> 00:18:00,880

continents

491

00:18:06,310 --> 00:18:03,440

separately from the actual time

492

00:18:09,190 --> 00:18:06,320

signatures of the received signal as the

493

00:18:10,310 --> 00:18:09,200

earth rotates that signal changes and

494

00:18:12,310 --> 00:18:10,320

they've demonstrated now in a

495

00:18:13,510 --> 00:18:12,320

paper-submitted app jay that this is in

496

00:18:14,710 --> 00:18:13,520

fact

497

00:18:16,549 --> 00:18:14,720

detectable

498

00:18:18,390 --> 00:18:16,559

i asked drake yesterday whether in fact

499

00:18:19,830 --> 00:18:18,400

you could distinguish dust storms on

500

00:18:22,150 --> 00:18:19,840

mars from

501
00:18:23,990 --> 00:18:22,160
an ocean on mars and uh he sort of

502
00:18:25,590 --> 00:18:24,000
looked at me strangely and

503
00:18:27,029 --> 00:18:25,600
waffled on the answer so if he's here

504
00:18:30,070 --> 00:18:27,039
today maybe he'll comment on that a

505
00:18:31,430 --> 00:18:30,080
little a little later

506
00:18:33,110 --> 00:18:31,440
so keep that if you have a question

507
00:18:34,310 --> 00:18:33,120
about this keep it in your mind because

508
00:18:35,909 --> 00:18:34,320
we're going to move right along to other

509
00:18:38,070 --> 00:18:35,919
topics

510
00:18:40,310 --> 00:18:38,080
okay moving along now and coming a

511
00:18:43,029 --> 00:18:40,320
little closer to home

512
00:18:45,830 --> 00:18:43,039
you have an active program in modeling

513
00:18:48,470 --> 00:18:45,840

chemical processes in

514

00:18:50,710 --> 00:18:48,480

nebulae that is to say dense clouds and

515

00:18:52,230 --> 00:18:50,720

also in the nebulae surrounding young

516

00:18:53,669 --> 00:18:52,240

stars

517

00:18:54,710 --> 00:18:53,679

i showed you this cartoon a little

518

00:18:56,390 --> 00:18:54,720

earlier

519

00:18:59,430 --> 00:18:56,400

steve charnley

520

00:19:00,390 --> 00:18:59,440

is now a uh here at goddard as a civil

521

00:19:02,310 --> 00:19:00,400

servant

522

00:19:04,070 --> 00:19:02,320

and he's leading a group

523

00:19:05,990 --> 00:19:04,080

as he has for the last

524

00:19:07,830 --> 00:19:06,000

five years as part of the iai and before

525

00:19:09,350 --> 00:19:07,840

that of course in his

526
00:19:11,430 --> 00:19:09,360
other life as

527
00:19:13,669 --> 00:19:11,440
just a general theorist

528
00:19:14,950 --> 00:19:13,679
doing uh chemistry

529
00:19:16,710 --> 00:19:14,960
uh on

530
00:19:17,590 --> 00:19:16,720
the processes that are occurring in this

531
00:19:19,909 --> 00:19:17,600
region

532
00:19:22,310 --> 00:19:19,919
and the idea here is to develop

533
00:19:24,950 --> 00:19:22,320
quantitative chemical models that

534
00:19:27,909 --> 00:19:24,960
then will permit uh their predictions to

535
00:19:30,310 --> 00:19:27,919
be compared with organic and isotopic

536
00:19:32,710 --> 00:19:30,320
inventories to help constrain the

537
00:19:34,789 --> 00:19:32,720
processes that actually occurred

538
00:19:36,870 --> 00:19:34,799

uh in the regions where this chemistry

539

00:19:38,950 --> 00:19:36,880

occurs namely from a few au out to

540

00:19:41,669 --> 00:19:38,960

perhaps 30 or 40 au

541

00:19:43,909 --> 00:19:41,679

from the young sun

542

00:19:45,990 --> 00:19:43,919

uh he also pursues

543

00:19:48,310 --> 00:19:46,000

certain astronomical

544

00:19:50,789 --> 00:19:48,320

problems through observations

545

00:19:53,909 --> 00:19:50,799

and this is in fact a detection of

546

00:19:55,990 --> 00:19:53,919

doubly deuterated formaldehyde

547

00:19:57,990 --> 00:19:56,000

in comet t7

548

00:20:00,150 --> 00:19:58,000

which appeared several years ago about

549

00:20:02,470 --> 00:20:00,160

six or seven years ago

550

00:20:03,830 --> 00:20:02,480

and indeed what's really amazing here is

551
00:20:05,750 --> 00:20:03,840
that sorry it's singly deuterated

552
00:20:06,390 --> 00:20:05,760
formaldehyde

553
00:20:13,270 --> 00:20:06,400
the

554
00:20:15,909 --> 00:20:13,280
indicative of ion molecule processing

555
00:20:18,630 --> 00:20:15,919
at low temperature and not of the doh

556
00:20:20,390 --> 00:20:18,640
ratio in the feedstock from which the

557
00:20:22,070 --> 00:20:20,400
ice is formed

558
00:20:24,549 --> 00:20:22,080
uh it was uh

559
00:20:25,830 --> 00:20:24,559
hd co₂h₂ co was on the order of 30

560
00:20:28,390 --> 00:20:25,840
percent

561
00:20:30,950 --> 00:20:28,400
uh instead of being depleted by a factor

562
00:20:32,789 --> 00:20:30,960
of 10 to the a few times uh

563
00:20:35,990 --> 00:20:32,799

well 50 000.

564

00:20:38,789 --> 00:20:36,000

so uh this was in fact evidence that at

565

00:20:42,310 --> 00:20:38,799

least in this comet legacy ices from the

566

00:20:43,510 --> 00:20:42,320

nato cloud core were incorporated or

567

00:20:46,870 --> 00:20:43,520

or

568

00:20:50,390 --> 00:20:46,880

uh the same class of chemistry affected

569

00:20:51,350 --> 00:20:50,400

isis in the solar system at a distance

570

00:20:53,510 --> 00:20:51,360

where

571

00:20:55,669 --> 00:20:53,520

the temperature was similar to that in

572

00:20:58,070 --> 00:20:55,679

the nato cloud core someone always has

573

00:21:00,149 --> 00:20:58,080

to remember there are multiple paths

574

00:21:02,070 --> 00:21:00,159

to explain a given database

575

00:21:03,510 --> 00:21:02,080

and additional tests are needed before

576

00:21:05,590 --> 00:21:03,520

you can constrain

577

00:21:08,549 --> 00:21:05,600

uh these two possibilities and we are

578

00:21:12,710 --> 00:21:10,789

so these are the sorts of things that

579

00:21:15,270 --> 00:21:12,720

steve is embarked upon there's a list

580

00:21:17,909 --> 00:21:15,280

here i don't intend to read this to you

581

00:21:20,230 --> 00:21:17,919

you'll all have to do that for yourself

582

00:21:21,430 --> 00:21:20,240

but the key point is that uh if you

583

00:21:23,830 --> 00:21:21,440

really want to know

584

00:21:27,909 --> 00:21:23,840

follow up this little more just

585

00:21:29,190 --> 00:21:27,919

google his uh his name and uh

586

00:21:30,950 --> 00:21:29,200

astral chemistry and you're going to

587

00:21:32,630 --> 00:21:30,960

find a whole host of papers he's a very

588

00:21:35,830 --> 00:21:32,640

productive and

589

00:21:40,390 --> 00:21:37,510

okay now the next thing i want to move

590

00:21:42,549 --> 00:21:40,400

on to is a work on sculpting of the

591

00:21:45,350 --> 00:21:42,559

early solar system this is uh to those

592

00:21:47,190 --> 00:21:45,360

of you who work on this uh field it's

593

00:21:49,750 --> 00:21:47,200

known as the niece model

594

00:21:51,029 --> 00:21:49,760

after the town in france where

595

00:21:53,830 --> 00:21:51,039

uh

596

00:21:56,789 --> 00:21:53,840

morbidelli and his collaborators reside

597

00:21:58,470 --> 00:21:56,799

at the observatory

598

00:22:01,750 --> 00:21:58,480

but anyway he uh

599

00:22:03,590 --> 00:22:01,760

they developed a model which um of which

600

00:22:06,110 --> 00:22:03,600

uh hal levison

601
00:22:09,590 --> 00:22:06,120
from swears and boulder is in fact a

602
00:22:11,190 --> 00:22:09,600
co-progenitor he actually and uh morby

603
00:22:12,870 --> 00:22:11,200
were two of the key uh leaders in

604
00:22:14,710 --> 00:22:12,880
developing this model

605
00:22:16,950 --> 00:22:14,720
and it had it was published for the

606
00:22:19,430 --> 00:22:16,960
first time in 2005

607
00:22:22,630 --> 00:22:19,440
and it is not too strong to say that it

608
00:22:25,669 --> 00:22:22,640
has revolutionized the field

609
00:22:27,669 --> 00:22:25,679
uh it's changed the understanding of

610
00:22:28,789 --> 00:22:27,679
almost everything from soup to nuts in

611
00:22:30,230 --> 00:22:28,799
terms of

612
00:22:32,149 --> 00:22:30,240
uh the

613
00:22:33,190 --> 00:22:32,159

dispersal of material in the early solar

614

00:22:35,430 --> 00:22:33,200

system

615

00:22:38,230 --> 00:22:35,440

so at the top we show a little cartoon

616

00:22:40,630 --> 00:22:38,240

which represents the giant planets

617

00:22:43,190 --> 00:22:40,640

the sun is on the far left then the

618

00:22:45,110 --> 00:22:43,200

5au from the sun five astronomical units

619

00:22:47,110 --> 00:22:45,120

for those of you who don't um

620

00:22:48,710 --> 00:22:47,120

or five times the earth distance from

621

00:22:50,230 --> 00:22:48,720

the sun for those of you who don't do

622

00:22:54,230 --> 00:22:50,240

astronomy

623

00:22:56,710 --> 00:22:54,240

uh as shown here then saturn and now the

624

00:22:59,510 --> 00:22:56,720

next planet out is not uranus as it is

625

00:23:01,190 --> 00:22:59,520

today but rather neptune that's this one

626

00:23:03,990 --> 00:23:01,200

and then uranus and both of those

627

00:23:05,990 --> 00:23:04,000

planets are within 15 a.u of the young

628

00:23:08,149 --> 00:23:06,000

sun which is very different from their

629

00:23:09,909 --> 00:23:08,159

current location

630

00:23:11,750 --> 00:23:09,919

beyond that there was a disk of icy

631

00:23:15,590 --> 00:23:11,760

planetesimals

632

00:23:18,070 --> 00:23:15,600

and now things start to get interesting

633

00:23:21,270 --> 00:23:18,080

jupiter and saturn are actually

634

00:23:23,990 --> 00:23:21,280

scattering bodies from their feeding

635

00:23:27,029 --> 00:23:24,000

zones in the first few hundred million

636

00:23:29,909 --> 00:23:27,039

years of solar system history and as

637

00:23:32,070 --> 00:23:29,919

they do that they have to move slightly

638

00:23:34,549 --> 00:23:32,080

from one another jupiter moving inward

639

00:23:37,270 --> 00:23:34,559

and saturn moving outward and when they

640

00:23:39,909 --> 00:23:37,280

hit uh orbital position such that their

641

00:23:41,830 --> 00:23:39,919

periods are in the ratio of two to one

642

00:23:44,549 --> 00:23:41,840

then they can pump each other or their

643

00:23:46,950 --> 00:23:44,559

gravity fields can work together to pump

644

00:23:49,029 --> 00:23:46,960

other bodies further out

645

00:23:51,590 --> 00:23:49,039

and disrupt this outer zone

646

00:23:52,870 --> 00:23:51,600

and what you'll notice here is that the

647

00:23:55,029 --> 00:23:52,880

um

648

00:23:56,630 --> 00:23:55,039

the planets neptune and uranus have

649

00:23:58,390 --> 00:23:56,640

swapped places

650

00:24:00,630 --> 00:23:58,400

and are moving outward

651
00:24:03,990 --> 00:24:00,640
and indeed are disrupting this outer

652
00:24:05,830 --> 00:24:04,000
disk of icy bodies we call this these

653
00:24:07,750 --> 00:24:05,840
planetesimals

654
00:24:09,270 --> 00:24:07,760
and finally as time goes on these are

655
00:24:11,830 --> 00:24:09,280
being scattered out some to the oort

656
00:24:14,310 --> 00:24:11,840
cloud some to the scattered kuiper disk

657
00:24:16,950 --> 00:24:14,320
and this is indeed the origin of the

658
00:24:18,710 --> 00:24:16,960
scattered kuiper disk until finally at

659
00:24:20,870 --> 00:24:18,720
the end of this process

660
00:24:21,909 --> 00:24:20,880
you end up with uranus at the correct

661
00:24:24,310 --> 00:24:21,919
position

662
00:24:27,110 --> 00:24:24,320
uh now inside of neptune which is out at

663
00:24:29,269 --> 00:24:27,120

30 a.u and finally the scattered kuiper

664

00:24:30,230 --> 00:24:29,279

disk in the classical cold disc further

665

00:24:32,470 --> 00:24:30,240

out

666

00:24:34,230 --> 00:24:32,480

this is a compelling model for several

667

00:24:36,310 --> 00:24:34,240

reasons

668

00:24:37,510 --> 00:24:36,320

it explains many puzzles

669

00:24:39,830 --> 00:24:37,520

uh

670

00:24:41,190 --> 00:24:39,840

regarding the solar system and here is a

671

00:24:44,310 --> 00:24:41,200

list of them

672

00:24:45,750 --> 00:24:44,320

in terms of astrobiology

673

00:24:47,750 --> 00:24:45,760

these of course are interesting for

674

00:24:50,149 --> 00:24:47,760

other reasons but uh the late heavy

675

00:24:51,830 --> 00:24:50,159

bombardment of the moon and earth uh

676
00:24:54,149 --> 00:24:51,840
occurs when the two to one mean motion

677
00:24:56,789 --> 00:24:54,159
resonance is reached and the outer disk

678
00:24:59,350 --> 00:24:56,799
uh is uh disseminated

679
00:25:01,750 --> 00:24:59,360
and that in their model is predicted to

680
00:25:03,029 --> 00:25:01,760
occur at just about the right time and

681
00:25:05,990 --> 00:25:03,039
about

682
00:25:08,710 --> 00:25:06,000
700 million years after formation of the

683
00:25:10,149 --> 00:25:08,720
sun or the earthquake system

684
00:25:11,510 --> 00:25:10,159
so that works pretty well and actually

685
00:25:13,669 --> 00:25:11,520
the massive material delivery to the

686
00:25:16,070 --> 00:25:13,679
moon also works well

687
00:25:19,350 --> 00:25:16,080
it also suggests that the original

688
00:25:22,149 --> 00:25:19,360

asteroid belt gets disrupted severely

689

00:25:25,110 --> 00:25:22,159

and delivers a massive bombardment

690

00:25:25,990 --> 00:25:25,120

it also in places the kuiper belt

691

00:25:28,230 --> 00:25:26,000

also

692

00:25:30,310 --> 00:25:28,240

suggests that this could create an early

693

00:25:31,510 --> 00:25:30,320

massive martian atmosphere and so forth

694

00:25:33,029 --> 00:25:31,520

and so on

695

00:25:35,430 --> 00:25:33,039

and it explains things like the

696

00:25:36,950 --> 00:25:35,440

irregular satellites of saturn here's

697

00:25:38,870 --> 00:25:36,960

one called phoebe

698

00:25:41,029 --> 00:25:38,880

which is basically if you like an icy

699

00:25:43,269 --> 00:25:41,039

planetesimal or comet nucleus but now in

700

00:25:45,110 --> 00:25:43,279

orbit around saturn

701
00:25:48,549 --> 00:25:45,120
having been scattered there by this

702
00:25:53,350 --> 00:25:50,390
so here's the way in which these

703
00:25:58,230 --> 00:25:54,830
produce

704
00:25:59,990 --> 00:25:58,240
testable uh signatures in the comet

705
00:26:02,470 --> 00:26:00,000
reservoirs

706
00:26:04,710 --> 00:26:02,480
uh firstly when the inner disc clears

707
00:26:05,590 --> 00:26:04,720
this is when the giant planets are first

708
00:26:07,750 --> 00:26:05,600
forming

709
00:26:09,590 --> 00:26:07,760
many of those planetesimals

710
00:26:11,590 --> 00:26:09,600
icy bodies are scattered to the oort

711
00:26:13,830 --> 00:26:11,600
cloud and some go into this outer icy

712
00:26:15,430 --> 00:26:13,840
disk which becomes a kuiper disk

713
00:26:17,590 --> 00:26:15,440

and then when the the

714

00:26:18,789 --> 00:26:17,600

motion resonance occurs and all heck

715

00:26:20,390 --> 00:26:18,799

breaks loose

716

00:26:22,149 --> 00:26:20,400

i got to keep it

717

00:26:23,269 --> 00:26:22,159

clean here

718

00:26:24,950 --> 00:26:23,279

the

719

00:26:27,190 --> 00:26:24,960

outer disk

720

00:26:28,950 --> 00:26:27,200

then disrupts and again

721

00:26:31,430 --> 00:26:28,960

scatters many bodies to the org cloud

722

00:26:33,590 --> 00:26:31,440

and some to the kuiper disk so

723

00:26:35,190 --> 00:26:33,600

a prediction of this model is that if

724

00:26:37,110 --> 00:26:35,200

there was a radial gradient with

725

00:26:39,750 --> 00:26:37,120

distance from the young sun

726
00:26:43,110 --> 00:26:39,760
then you should see diverse chemistries

727
00:26:45,909 --> 00:26:43,120
of icy bodies in both reservoirs

728
00:26:48,950 --> 00:26:45,919
and finally the diversity quotients that

729
00:26:51,190 --> 00:26:48,960
is to say that if you have

730
00:26:53,110 --> 00:26:51,200
four or five classes of organic

731
00:26:55,269 --> 00:26:53,120
chemistries in individual bodies in

732
00:26:57,909 --> 00:26:55,279
these reservoirs you might have more of

733
00:26:59,029 --> 00:26:57,919
type a in the first reservoir kuiper

734
00:27:01,590 --> 00:26:59,039
belt and

735
00:27:03,669 --> 00:27:01,600
less of type a and york cloud which is

736
00:27:05,430 --> 00:27:03,679
of course mainly formed from

737
00:27:06,710 --> 00:27:05,440
bodies that were formed closer into the

738
00:27:08,149 --> 00:27:06,720

sun

739

00:27:10,470 --> 00:27:08,159

so these are

740

00:27:11,830 --> 00:27:10,480

then can be compared with cometary

741

00:27:14,950 --> 00:27:11,840

composition

742

00:27:16,390 --> 00:27:14,960

to indeed see do we see diversity uh are

743

00:27:18,470 --> 00:27:16,400

they different than two reservoirs and

744

00:27:22,549 --> 00:27:18,480

so forth and so on and then by going

745

00:27:25,110 --> 00:27:22,559

back and forth one can revise the models

746

00:27:27,909 --> 00:27:25,120

and theory and so forth and so on and so

747

00:27:29,590 --> 00:27:27,919

that is where we are going with this

748

00:27:31,669 --> 00:27:29,600

the current observables the top three

749

00:27:34,230 --> 00:27:31,679

bullets there check marks

750

00:27:36,230 --> 00:27:34,240

basically are the things we see these

751

00:27:38,630 --> 00:27:36,240

distinct classes of comets

752

00:27:39,909 --> 00:27:38,640

uh chemical models that independently

753

00:27:41,830 --> 00:27:39,919

predict radio radiance and

754

00:27:43,269 --> 00:27:41,840

protoplanetary disks

755

00:27:44,710 --> 00:27:43,279

and finally the nice model which

756

00:27:46,230 --> 00:27:44,720

predicts significant mixing into

757

00:27:48,950 --> 00:27:46,240

different reservoirs

758

00:27:51,350 --> 00:27:48,960

although it it really desperately needs

759

00:27:53,510 --> 00:27:51,360

some of the constraints provided by the

760

00:27:55,669 --> 00:27:53,520

first tick mark in order to further

761

00:27:58,710 --> 00:27:55,679

refine the nice model

762

00:28:00,389 --> 00:27:58,720

and then finally uh the circled bullets

763

00:28:03,669 --> 00:28:00,399

below show what

764

00:28:05,669 --> 00:28:03,679

is planned by hal for his immediate work

765

00:28:07,269 --> 00:28:05,679

in the next five years during this uh

766

00:28:08,710 --> 00:28:07,279

pattern you can read that for yourself

767

00:28:11,909 --> 00:28:08,720

uh when the

768

00:28:14,710 --> 00:28:11,919

powerpoint file has been posted

769

00:28:16,870 --> 00:28:14,720

okay uh so here are the ground truths

770

00:28:18,470 --> 00:28:16,880

that we have to work with

771

00:28:20,070 --> 00:28:18,480

icy bodies

772

00:28:21,510 --> 00:28:20,080

from new york cloud and the kuiper disk

773

00:28:24,070 --> 00:28:21,520

we can tell which where they came from

774

00:28:26,630 --> 00:28:24,080

based on their orbital parameters

775

00:28:28,389 --> 00:28:26,640

uh but not where they originally formed

776

00:28:31,430 --> 00:28:28,399

from their orbital parameters that that

777

00:28:33,750 --> 00:28:31,440

information was lost uh

778

00:28:35,990 --> 00:28:33,760

also looking at lunar brushes and

779

00:28:38,070 --> 00:28:36,000

finally looking at meteorites

780

00:28:39,990 --> 00:28:38,080

so let's have a look first at uh just a

781

00:28:44,549 --> 00:28:40,000

quick overview of what we're learning

782

00:28:46,870 --> 00:28:44,559

about the taxonomy of icy planetesimals

783

00:28:48,789 --> 00:28:46,880

okay so here's what we want to do we're

784

00:28:50,870 --> 00:28:48,799

going to do this all three steps and

785

00:28:54,710 --> 00:28:50,880

these are well in hand now and we have

786

00:28:56,870 --> 00:28:54,720

about 21 comments in our database so far

787

00:28:59,990 --> 00:28:56,880

of which i'll show you results based on

788

00:29:02,789 --> 00:29:00,000

12. the others we just published three

789

00:29:05,110 --> 00:29:02,799

more haven't yet made it into this

790

00:29:07,430 --> 00:29:05,120

the synopsis that i'll show you

791

00:29:09,029 --> 00:29:07,440

uh but we'll in a few months and then so

792

00:29:11,669 --> 00:29:09,039

forth and so on so we're accumulating

793

00:29:12,870 --> 00:29:11,679

new bodies roughly two per year

794

00:29:15,190 --> 00:29:12,880

we could do more if we had more

795

00:29:16,470 --> 00:29:15,200

observing time

796

00:29:18,310 --> 00:29:16,480

okay so

797

00:29:20,630 --> 00:29:18,320

i showed you this picture of phoebe at

798

00:29:23,029 --> 00:29:20,640

the upper right before and i show you

799

00:29:24,230 --> 00:29:23,039

the actual images of distinct iconic

800

00:29:26,389 --> 00:29:24,240

nuclei

801
00:29:29,430 --> 00:29:26,399
for one and only one reason and that is

802
00:29:32,310 --> 00:29:29,440
to show you or tell you basically uh we

803
00:29:35,029 --> 00:29:32,320
can discuss this later as to whether you

804
00:29:37,590 --> 00:29:35,039
understand it but you do not learn

805
00:29:39,510 --> 00:29:37,600
much about the origin of the cometary

806
00:29:41,029 --> 00:29:39,520
bodies by looking at images of the

807
00:29:44,310 --> 00:29:41,039
surface

808
00:29:46,710 --> 00:29:44,320
take away message number one

809
00:29:48,549 --> 00:29:46,720
take away message number two

810
00:29:50,950 --> 00:29:48,559
if you look at the individual parent

811
00:29:53,830 --> 00:29:50,960
volatiles these are we call these parent

812
00:29:56,950 --> 00:29:53,840
volatiles are the chemicals that were

813
00:29:58,789 --> 00:29:56,960

formed as ices in the cometary nucleus

814

00:30:01,750 --> 00:29:58,799

were sublimated as the nucleus became

815

00:30:04,710 --> 00:30:01,760

activated by solar heat entered the coma

816

00:30:07,430 --> 00:30:04,720

and now can be measured these are

817

00:30:08,870 --> 00:30:07,440

being pursued vigorously by millimeter

818

00:30:09,990 --> 00:30:08,880

and infrared

819

00:30:12,789 --> 00:30:10,000

observers

820

00:30:13,750 --> 00:30:12,799

we do mainly infrared work but we

821

00:30:15,909 --> 00:30:13,760

also

822

00:30:17,029 --> 00:30:15,919

are teamed with several groups that do

823

00:30:18,870 --> 00:30:17,039

millimeter

824

00:30:21,590 --> 00:30:18,880

observing as well

825

00:30:24,310 --> 00:30:21,600

including astronomers at uh

826

00:30:26,230 --> 00:30:24,320

university of arizona smt also at

827

00:30:28,950 --> 00:30:26,240

university of hawaii and so forth

828

00:30:30,710 --> 00:30:28,960

through the karamieches team

829

00:30:33,029 --> 00:30:30,720

uh so here on the right you see a list

830

00:30:35,590 --> 00:30:33,039

of molecules that are are

831

00:30:37,830 --> 00:30:35,600

have been detected so far and the red

832

00:30:40,789 --> 00:30:37,840

bar in each case gives you an idea of

833

00:30:42,389 --> 00:30:40,799

the range of abundance ratios seen

834

00:30:44,149 --> 00:30:42,399

uh if seen in a number of comets here

835

00:30:45,830 --> 00:30:44,159

for example co

836

00:30:47,750 --> 00:30:45,840

is seen in more than 10 comets it's

837

00:30:50,149 --> 00:30:47,760

about 20 by now

838

00:30:52,549 --> 00:30:50,159

and it ranges by almost a factor of 100

839

00:30:54,149 --> 00:30:52,559

in abundance relative to water obviously

840

00:30:55,430 --> 00:30:54,159

a clear measure of significant

841

00:30:57,269 --> 00:30:55,440

variability

842

00:30:58,950 --> 00:30:57,279

on the other hand there are a few other

843

00:31:01,269 --> 00:30:58,960

chemicals that are seen in only one

844

00:31:02,070 --> 00:31:01,279

comet namely hal bot the brightest comet

845

00:31:04,389 --> 00:31:02,080

ever

846

00:31:06,070 --> 00:31:04,399

quantified with modern instrumentation

847

00:31:08,710 --> 00:31:06,080

and so we don't have much information

848

00:31:10,310 --> 00:31:08,720

from them except an existence theorem we

849

00:31:13,990 --> 00:31:10,320

don't know much about how that that

850

00:31:16,950 --> 00:31:14,000

varies from uh body to body

851
00:31:18,470 --> 00:31:16,960
now the infrared is especially powerful

852
00:31:21,029 --> 00:31:18,480
in this regard

853
00:31:24,070 --> 00:31:21,039
and the key reason is the advent of

854
00:31:26,630 --> 00:31:24,080
cross-dispersed shell spectrometers

855
00:31:28,630 --> 00:31:26,640
particularly at keck

856
00:31:31,110 --> 00:31:28,640
and on the left here you see a list of

857
00:31:33,750 --> 00:31:31,120
chemicals all of which can be measured

858
00:31:35,909 --> 00:31:33,760
simultaneously with water

859
00:31:36,789 --> 00:31:35,919
and when i say simultaneously i mean at

860
00:31:38,389 --> 00:31:36,799
every

861
00:31:40,389 --> 00:31:38,399
point along the

862
00:31:41,509 --> 00:31:40,399
entrance aperture of the spectrometer we

863
00:31:43,830 --> 00:31:41,519

can measure

864

00:31:46,549 --> 00:31:43,840

half a dozen of these species and water

865

00:31:48,149 --> 00:31:46,559

always at the same time

866

00:31:50,389 --> 00:31:48,159

enough said

867

00:31:52,950 --> 00:31:50,399

i won't go into any more detail

868

00:31:54,230 --> 00:31:52,960

than that except to tell you that when

869

00:31:57,029 --> 00:31:54,240

we do that

870

00:31:58,950 --> 00:31:57,039

we have removed most sources of

871

00:32:01,350 --> 00:31:58,960

systematic error

872

00:32:02,950 --> 00:32:01,360

as if you did each molecule separately

873

00:32:04,310 --> 00:32:02,960

on say night to night or with different

874

00:32:05,590 --> 00:32:04,320

instruments then you'd always have to

875

00:32:07,110 --> 00:32:05,600

worry about

876

00:32:09,269 --> 00:32:07,120

observational

877

00:32:12,630 --> 00:32:09,279

artifacts such as the atmospheric

878

00:32:14,950 --> 00:32:12,640

turbulence and so forth and so on

879

00:32:17,269 --> 00:32:14,960

well let's look at how these uh these

880

00:32:18,310 --> 00:32:17,279

comets stack up when once against one

881

00:32:20,470 --> 00:32:18,320

another

882

00:32:22,389 --> 00:32:20,480

and this uh this slide i want you to

883

00:32:24,870 --> 00:32:22,399

draw attention to

884

00:32:26,389 --> 00:32:24,880

uh two aspects of it

885

00:32:28,230 --> 00:32:26,399

first um

886

00:32:29,750 --> 00:32:28,240

the comet number there's a key on the

887

00:32:31,590 --> 00:32:29,760

left you can look at that later on it

888

00:32:34,070 --> 00:32:31,600

doesn't really matter for the moment

889

00:32:35,590 --> 00:32:34,080

it's given by and on the bottom axis so

890

00:32:38,230 --> 00:32:35,600

these are just individual comments

891

00:32:40,549 --> 00:32:38,240

running from left to right

892

00:32:42,230 --> 00:32:40,559

next i want you to look at this chart

893

00:32:44,389 --> 00:32:42,240

right here which shows you the abundance

894

00:32:46,230 --> 00:32:44,399

of methanol these two comets have

895

00:32:48,230 --> 00:32:46,240

methanol in the order of four percent

896

00:32:50,710 --> 00:32:48,240

relative to water

897

00:32:52,310 --> 00:32:50,720

the next group uh has methanol at about

898

00:32:53,830 --> 00:32:52,320

two percent relative to water and then

899

00:32:56,630 --> 00:32:53,840

finally there's a group over here where

900

00:32:59,350 --> 00:32:56,640

it's depleted by an order of magnitude

901
00:33:00,389 --> 00:32:59,360
same thing happens for ethane

902
00:33:02,389 --> 00:33:00,399
the last

903
00:33:03,830 --> 00:33:02,399
molecule that i will mention and i would

904
00:33:05,110 --> 00:33:03,840
just tell you that these two are highly

905
00:33:06,149 --> 00:33:05,120
correlated i'll show you in the next

906
00:33:08,549 --> 00:33:06,159
slide

907
00:33:10,389 --> 00:33:08,559
but notice that for the high ethane

908
00:33:12,549 --> 00:33:10,399
comets there's one from the oort cloud

909
00:33:14,470 --> 00:33:12,559
and one from the kuiper belt and from

910
00:33:15,590 --> 00:33:14,480
the the low methanol comets there's one

911
00:33:16,789 --> 00:33:15,600
from new york cloud and one from the

912
00:33:19,509 --> 00:33:16,799
kuiper belt

913
00:33:21,110 --> 00:33:19,519

yet normal populations are dominated by

914

00:33:23,750 --> 00:33:21,120

the orc cloud just because we have more

915

00:33:26,389 --> 00:33:23,760

of those in our database but we do also

916

00:33:28,549 --> 00:33:26,399

see some in the kuiper belt so here you

917

00:33:30,310 --> 00:33:28,559

see immediate evidence

918

00:33:32,870 --> 00:33:30,320

out of the three distinct groups of

919

00:33:35,110 --> 00:33:32,880

comets members of each group are found

920

00:33:37,430 --> 00:33:35,120

in each dynamical reservoir

921

00:33:40,230 --> 00:33:37,440

that tells you that

922

00:33:42,870 --> 00:33:40,240

the key will be to identify

923

00:33:44,710 --> 00:33:42,880

the fractions of each class that are in

924

00:33:45,430 --> 00:33:44,720

each reservoir because that's what tells

925

00:33:46,470 --> 00:33:45,440

you

926
00:33:48,389 --> 00:33:46,480
uh

927
00:33:50,070 --> 00:33:48,399
the something about the dynamics in the

928
00:33:52,310 --> 00:33:50,080
region of the solar system from each

929
00:33:54,310 --> 00:33:52,320
which each reservoir received its

930
00:33:56,389 --> 00:33:54,320
numbers

931
00:33:58,549 --> 00:33:56,399
now i promise to show you those same uh

932
00:34:00,950 --> 00:33:58,559
two data sets on ethane in a different

933
00:34:02,950 --> 00:34:00,960
way and here it is shown as a bar chart

934
00:34:04,070 --> 00:34:02,960
uh basically this is a factor of two in

935
00:34:05,750 --> 00:34:04,080
each case

936
00:34:08,149 --> 00:34:05,760
here's the normal population you can see

937
00:34:10,230 --> 00:34:08,159
about a dozen comets in that maybe it's

938
00:34:11,190 --> 00:34:10,240

actually 10 7 8 9

939

00:34:12,710 --> 00:34:11,200

10.

940

00:34:14,629 --> 00:34:12,720

the enriched group is over here and

941

00:34:16,470 --> 00:34:14,639

there's a depleted group here and the

942

00:34:18,389 --> 00:34:16,480

methanol shows a somewhat similar

943

00:34:20,710 --> 00:34:18,399

distribution so we think these are

944

00:34:22,230 --> 00:34:20,720

probably uh

945

00:34:23,510 --> 00:34:22,240

somewhat realistic we don't know yet

946

00:34:25,190 --> 00:34:23,520

whether this is going to fill in and

947

00:34:28,069 --> 00:34:25,200

become just a single

948

00:34:33,510 --> 00:34:28,079

broad distribution but so far we really

949

00:34:37,829 --> 00:34:35,030

uh there are two other parameters we're

950

00:34:40,950 --> 00:34:37,839

after which will tell us more about uh

951

00:34:44,149 --> 00:34:40,960

uh the uh place of origin in the

952

00:34:45,909 --> 00:34:44,159

protoplanetary disk or natal cloud core

953

00:34:48,389 --> 00:34:45,919

uh the first one is the so-called

954

00:34:50,389 --> 00:34:48,399

nuclear spin temperature

955

00:34:52,950 --> 00:34:50,399

in water and now it's being pursued in

956

00:34:55,669 --> 00:34:52,960

ammonia and methane as well

957

00:34:58,550 --> 00:34:55,679

basically this the idea here is that

958

00:35:00,150 --> 00:34:58,560

the proton carries a spin of one half

959

00:35:02,390 --> 00:35:00,160

speed angular momentum so if you have

960

00:35:04,470 --> 00:35:02,400

two protons those spins can be aligned

961

00:35:05,670 --> 00:35:04,480

or anti-aligned to give you one or zero

962

00:35:07,910 --> 00:35:05,680

as a total

963

00:35:09,589 --> 00:35:07,920

and this gives you different weights and

964

00:35:11,589 --> 00:35:09,599

they have slightly different lower state

965

00:35:12,630 --> 00:35:11,599

energies so you can have a temperature

966

00:35:14,790 --> 00:35:12,640

effect

967

00:35:16,390 --> 00:35:14,800

uh if they formed at low temperature

968

00:35:18,790 --> 00:35:16,400

you'll have very little of the highest

969

00:35:20,790 --> 00:35:18,800

higher excitation state if they formed a

970

00:35:22,950 --> 00:35:20,800

higher temperature you'll have a lot and

971

00:35:24,630 --> 00:35:22,960

so here's an example for

972

00:35:27,030 --> 00:35:24,640

about a dozen comets

973

00:35:28,710 --> 00:35:27,040

showing the range of such uh

974

00:35:31,109 --> 00:35:28,720

spin temperatures measured in these

975

00:35:34,150 --> 00:35:31,119

different comets and they typically

976
00:35:35,270 --> 00:35:34,160
range i'd say a modal value is around 30

977
00:35:36,950 --> 00:35:35,280
kelvin

978
00:35:38,470 --> 00:35:36,960
which is

979
00:35:39,829 --> 00:35:38,480
cold enough to actually cause these

980
00:35:41,109 --> 00:35:39,839
spins to be

981
00:35:42,470 --> 00:35:41,119
relaxed

982
00:35:44,630 --> 00:35:42,480
and so this gives you a way of

983
00:35:46,230 --> 00:35:44,640
identifying something about the origin

984
00:35:47,349 --> 00:35:46,240
of the water in a given comet in this

985
00:35:49,829 --> 00:35:47,359
way

986
00:35:51,750 --> 00:35:49,839
the second modality is to look at the d

987
00:35:53,910 --> 00:35:51,760
to h ratio

988
00:35:56,630 --> 00:35:53,920

in individual volatiles

989

00:35:59,990 --> 00:35:56,640

and that's been pursued mainly for water

990

00:36:01,829 --> 00:36:00,000

vapor but a little for hcn and

991

00:36:03,670 --> 00:36:01,839

people are on the track of doing it as

992

00:36:05,829 --> 00:36:03,680

you heard a minute ago for formaldehyde

993

00:36:08,230 --> 00:36:05,839

hdco in particular

994

00:36:10,550 --> 00:36:08,240

but also for

995

00:36:12,470 --> 00:36:10,560

other species such as deuterated ethane

996

00:36:15,109 --> 00:36:12,480

and deuterated methane

997

00:36:16,950 --> 00:36:15,119

the key point is that

998

00:36:17,990 --> 00:36:16,960

the take-home messages

999

00:36:19,430 --> 00:36:18,000

although

1000

00:36:21,829 --> 00:36:19,440

so far

1001
00:36:25,589 --> 00:36:21,839
most comets that have been sampled

1002
00:36:26,390 --> 00:36:25,599
show a ddoh ratio of about

1003
00:36:28,790 --> 00:36:26,400
twice

1004
00:36:31,190 --> 00:36:28,800
that found in mean ocean water

1005
00:36:33,190 --> 00:36:31,200
uh we think that may be related to the

1006
00:36:34,950 --> 00:36:33,200
fact that they are all of the same

1007
00:36:36,950 --> 00:36:34,960
organic group

1008
00:36:39,990 --> 00:36:36,960
they are all organics normal comets we

1009
00:36:41,990 --> 00:36:40,000
don't yet see any feta have not gotten a

1010
00:36:44,630 --> 00:36:42,000
d2h measurement in any comet that is

1011
00:36:47,030 --> 00:36:44,640
organics depleted which is the signature

1012
00:36:48,790 --> 00:36:47,040
we think of forming in the higher

1013
00:36:52,150 --> 00:36:48,800

temperature region

1014

00:36:53,510 --> 00:36:52,160
of jupiter saturn or even closer

1015

00:36:55,750 --> 00:36:53,520
well

1016

00:36:57,750 --> 00:36:55,760
uh let's see we'll come back to that in

1017

00:37:00,390 --> 00:36:57,760
a moment but uh

1018

00:37:02,630 --> 00:37:00,400
let me just say then that of the

1019

00:37:04,150 --> 00:37:02,640
data set that i showed you a minute ago

1020

00:37:06,310 --> 00:37:04,160
here are the key parameters we're after

1021

00:37:08,790 --> 00:37:06,320
we only have d2h and

1022

00:37:10,790 --> 00:37:08,800
three such comets in this group that i'm

1023

00:37:12,550 --> 00:37:10,800
showing the temp spin temperatures in a

1024

00:37:13,430 --> 00:37:12,560
few comets

1025

00:37:15,750 --> 00:37:13,440
and

1026

00:37:18,310 --> 00:37:15,760

in those comets we also have good uh

1027

00:37:21,270 --> 00:37:18,320

organic composition so

1028

00:37:23,190 --> 00:37:21,280

very crudely and and perhaps incorrectly

1029

00:37:24,790 --> 00:37:23,200

we don't know for this for sure but

1030

00:37:26,950 --> 00:37:24,800

there's a suggestion

1031

00:37:28,950 --> 00:37:26,960

that the high temperature comets that

1032

00:37:31,589 --> 00:37:28,960

show high spin temperatures are the ones

1033

00:37:35,109 --> 00:37:31,599

that have depleted organics

1034

00:37:37,589 --> 00:37:35,119

the very lowest temperature spin uh

1035

00:37:39,349 --> 00:37:37,599

if you like is t spin about 21

1036

00:37:41,910 --> 00:37:39,359

kelvin which suggests they they were

1037

00:37:44,310 --> 00:37:41,920

have very high uh

1038

00:37:45,990 --> 00:37:44,320

uh are enriched in organics

1039

00:37:47,829 --> 00:37:46,000

and the organic normal seem to be

1040

00:37:51,349 --> 00:37:47,839

intermediate

1041

00:37:53,430 --> 00:37:51,359

very very incomplete data set it's

1042

00:37:55,670 --> 00:37:53,440

expanding rapidly but in the next five

1043

00:37:57,829 --> 00:37:55,680

years we intend to fill this in

1044

00:37:59,910 --> 00:37:57,839

extensively and hopefully we'll have a

1045

00:38:01,750 --> 00:37:59,920

far more definitive

1046

00:38:05,430 --> 00:38:01,760

story to tell you about that this is

1047

00:38:07,750 --> 00:38:05,440

work in progress at the present time

1048

00:38:09,990 --> 00:38:07,760

okay i'm just going to flash this uh

1049

00:38:11,750 --> 00:38:10,000

chart you can actually uh read this once

1050

00:38:14,790 --> 00:38:11,760

the powerpoint is

1051
00:38:16,550 --> 00:38:14,800
is posted but basically as a synopsis of

1052
00:38:20,230 --> 00:38:16,560
what we've learned so far and what i've

1053
00:38:22,230 --> 00:38:20,240
told you and where we're going in future

1054
00:38:24,790 --> 00:38:22,240
now the second ground truth we should

1055
00:38:26,630 --> 00:38:24,800
turn to is not remote observations but

1056
00:38:29,990 --> 00:38:26,640
observations uh measurements in the

1057
00:38:32,470 --> 00:38:30,000
laboratory on on authentic samples

1058
00:38:35,190 --> 00:38:32,480
especially of extraterrestrial organics

1059
00:38:37,030 --> 00:38:35,200
returned by meteorites and also by

1060
00:38:38,310 --> 00:38:37,040
stardust samples

1061
00:38:40,950 --> 00:38:38,320
i think you've

1062
00:38:44,630 --> 00:38:40,960
heard some of some aspects of

1063
00:38:46,470 --> 00:38:44,640

similar work from the carnegie team

1064

00:38:48,230 --> 00:38:46,480

when george presented his summary

1065

00:38:50,390 --> 00:38:48,240

earlier on

1066

00:38:51,990 --> 00:38:50,400

uh in any case this is being done now in

1067

00:38:55,190 --> 00:38:52,000

the advanced uh we call it the

1068

00:38:56,630 --> 00:38:55,200

astrobiology analysis lab uh here at

1069

00:38:59,270 --> 00:38:56,640

goddard

1070

00:39:01,349 --> 00:38:59,280

uh under the direction of jason dworkin

1071

00:39:04,390 --> 00:39:01,359

with collaborators showing down here

1072

00:39:07,030 --> 00:39:04,400

mike callahan is a postdoc uh

1073

00:39:08,470 --> 00:39:07,040

jamie also a cook and danny glavin zito

1074

00:39:10,470 --> 00:39:08,480

martin and

1075

00:39:12,790 --> 00:39:10,480

jen stern

1076

00:39:15,670 --> 00:39:12,800

and uh what

1077

00:39:19,430 --> 00:39:15,680

we actually started with a bare bones uh

1078

00:39:20,630 --> 00:39:19,440

derelict lab four years ago five years

1079

00:39:23,750 --> 00:39:20,640

ago and

1080

00:39:25,910 --> 00:39:23,760

then jason converted that into a

1081

00:39:28,390 --> 00:39:25,920

state-of-the-art

1082

00:39:29,750 --> 00:39:28,400

uh laboratory for analysis of complex

1083

00:39:33,270 --> 00:39:29,760

organics

1084

00:39:34,950 --> 00:39:33,280

uh in these samples

1085

00:39:37,109 --> 00:39:34,960

uh let's take an example of something

1086

00:39:40,870 --> 00:39:37,119

that he's uh

1087

00:39:44,069 --> 00:39:43,030

using the stardust

1088

00:39:47,190 --> 00:39:44,079

uh

1089

00:39:49,349 --> 00:39:47,200

oil samples not the actual grain samples

1090

00:39:51,990 --> 00:39:49,359

themselves or grain tracks

1091

00:39:54,870 --> 00:39:52,000

but uh taking samples of aluminum foil

1092

00:39:56,950 --> 00:39:54,880

that were actually uh used to

1093

00:40:00,150 --> 00:39:56,960

isolate the

1094

00:40:01,430 --> 00:40:00,160

cells and also to

1095

00:40:02,790 --> 00:40:01,440

essentially

1096

00:40:05,030 --> 00:40:02,800

protect them

1097

00:40:07,349 --> 00:40:05,040

but in many cases these things are

1098

00:40:08,470 --> 00:40:07,359

impacted by cometary

1099

00:40:10,470 --> 00:40:08,480

gases

1100

00:40:12,390 --> 00:40:10,480

and occasionally grains

1101

00:40:15,510 --> 00:40:12,400

and the point is on the back side of

1102

00:40:18,630 --> 00:40:15,520

these cells actually found evidence for

1103

00:40:20,870 --> 00:40:18,640

uh two uh different uh compounds

1104

00:40:23,589 --> 00:40:20,880

methylamine and ethylamine

1105

00:40:25,990 --> 00:40:23,599

here and here and uh

1106

00:40:28,710 --> 00:40:26,000

there's some possibility that these were

1107

00:40:31,190 --> 00:40:28,720

in fact uh either reacted within the

1108

00:40:33,270 --> 00:40:31,200

foil from methane and ammonia

1109

00:40:34,630 --> 00:40:33,280

injected by the comet or

1110

00:40:36,069 --> 00:40:34,640

actually could have been present as

1111

00:40:38,150 --> 00:40:36,079

these compounds in the cometary

1112

00:40:40,069 --> 00:40:38,160

atmosphere itself i think jason's

1113

00:40:42,150 --> 00:40:40,079

standing by to ask answer questions

1114

00:40:44,230 --> 00:40:42,160

about that if you'd like to ask sent any

1115

00:40:45,990 --> 00:40:44,240

during the question period

1116

00:40:49,109 --> 00:40:46,000

lately they've been looking for uh

1117

00:40:50,829 --> 00:40:49,119

cometary glycine

1118

00:40:54,550 --> 00:40:50,839

uh and a

1119

00:40:57,589 --> 00:40:54,560

particular this is

1120

00:41:01,030 --> 00:40:57,599

the isotopic enrichment for

1121

00:41:04,790 --> 00:41:01,040

uh delta 13c in glycine

1122

00:41:06,950 --> 00:41:04,800

as uh derived by jamie elsala

1123

00:41:08,630 --> 00:41:06,960

and what you'll notice is that uh it

1124

00:41:10,230 --> 00:41:08,640

does appear to have an extraterrestrial

1125

00:41:11,990 --> 00:41:10,240

signature

1126

00:41:15,510 --> 00:41:12,000

uh this has now been submitted for

1127

00:41:18,230 --> 00:41:15,520

publication uh i think uh two weeks ago

1128

00:41:20,150 --> 00:41:18,240

uh and so this work is uh

1129

00:41:21,750 --> 00:41:20,160

proprietary and should not be

1130

00:41:24,550 --> 00:41:21,760

distributed further

1131

00:41:26,390 --> 00:41:24,560

uh until after it has been accepted and

1132

00:41:28,309 --> 00:41:26,400

pre-points are distributed

1133

00:41:30,230 --> 00:41:28,319

uh so have a good look at this slide you

1134

00:41:31,109 --> 00:41:30,240

will not see it in our public version of

1135

00:41:32,790 --> 00:41:31,119

the

1136

00:41:34,950 --> 00:41:32,800

talk to be

1137

00:41:37,670 --> 00:41:34,960

placed on the website

1138

00:41:39,910 --> 00:41:37,680

but uh the net uh you should take away

1139

00:41:41,190 --> 00:41:39,920

messages that there is glycine present

1140

00:41:42,550 --> 00:41:41,200

in the sample

1141

00:41:44,950 --> 00:41:42,560

uh and it does appear to have an

1142

00:41:47,270 --> 00:41:44,960

extraterrestrial signature it is not

1143

00:41:48,069 --> 00:41:47,280

depleted in

1144

00:41:49,910 --> 00:41:48,079

c

1145

00:41:51,589 --> 00:41:49,920

by the 20 to 70 part tremel that you

1146

00:41:55,910 --> 00:41:51,599

would normally expect for

1147

00:42:01,430 --> 00:41:59,270

now one result that in fact is published

1148

00:42:03,349 --> 00:42:01,440

is this one by

1149

00:42:04,870 --> 00:42:03,359

glavine and dworkin in which they look

1150

00:42:07,030 --> 00:42:04,880

for uh

1151
00:42:09,510 --> 00:42:07,040
enantiomeric excesses

1152
00:42:11,349 --> 00:42:09,520
and amino acids in meteoritics

1153
00:42:13,270 --> 00:42:11,359
particularly the

1154
00:42:15,190 --> 00:42:13,280
carbonaceous chondrites

1155
00:42:16,390 --> 00:42:15,200
murchison which is a cm and several

1156
00:42:18,950 --> 00:42:16,400
others

1157
00:42:20,390 --> 00:42:18,960
and the key point is that they have in

1158
00:42:24,230 --> 00:42:20,400
fact

1159
00:42:25,750 --> 00:42:24,240
seen a very large excess in

1160
00:42:28,630 --> 00:42:25,760
surveilling

1161
00:42:31,670 --> 00:42:28,640
reported at 18 percent

1162
00:42:34,950 --> 00:42:31,680
and uh is largest uh scene to date they

1163
00:42:36,550 --> 00:42:34,960

now have um I to the access ratios and

1164

00:42:39,990 --> 00:42:36,560

and i think it's four

1165

00:42:41,910 --> 00:42:40,000

uh examples of uh perimeter meteorites

1166

00:42:43,829 --> 00:42:41,920

you can read this in pnas it just came

1167

00:42:47,030 --> 00:42:43,839

out or it's about to it's online now in

1168

00:42:48,069 --> 00:42:47,040

the penis under laven and dworkin

1169

00:42:50,550 --> 00:42:48,079

and uh

1170

00:42:52,470 --> 00:42:50,560

earlier uh papers were published on some

1171

00:42:53,990 --> 00:42:52,480

aspects of the work but this is the

1172

00:42:58,069 --> 00:42:54,000

definitive work

1173

00:42:59,270 --> 00:42:58,079

one of the keys was to identify um

1174

00:43:01,270 --> 00:42:59,280

a uh

1175

00:43:02,710 --> 00:43:01,280

i guess it's actually later on in

1176

00:43:06,710 --> 00:43:02,720

another view graph which i'll show you

1177

00:43:09,829 --> 00:43:06,720

but there can be another uh

1178

00:43:12,790 --> 00:43:09,839

organic which eludes together with uh ly

1179

00:43:14,870 --> 00:43:12,800

surveillance which they successfully uh

1180

00:43:17,510 --> 00:43:14,880

isolated and separated

1181

00:43:19,750 --> 00:43:17,520

which permits uh unique conclusions

1182

00:43:22,309 --> 00:43:19,760

shown here

1183

00:43:25,030 --> 00:43:22,319

okay then other aspects of work that's

1184

00:43:27,990 --> 00:43:25,040

going on is to look at specific isotopic

1185

00:43:30,630 --> 00:43:28,000

analyses this is with the

1186

00:43:32,470 --> 00:43:30,640

isotope ratio mass spectrometer which

1187

00:43:35,510 --> 00:43:32,480

goddard funded this was not funded

1188

00:43:38,069 --> 00:43:35,520

through nai most of the early

1189

00:43:39,430 --> 00:43:38,079

analytical tools were funded through the

1190

00:43:41,510 --> 00:43:39,440

gca

1191

00:43:43,510 --> 00:43:41,520

team budget summed by goddard through

1192

00:43:46,550 --> 00:43:43,520

matching funds and so on

1193

00:43:47,750 --> 00:43:46,560

but the new irms is uh funded wholly by

1194

00:43:50,069 --> 00:43:47,760

goddard

1195

00:43:52,710 --> 00:43:50,079

uh and again here's the process to look

1196

00:43:55,349 --> 00:43:52,720

for these n heterocycles

1197

00:43:57,750 --> 00:43:55,359

and then establish their isotopic ratios

1198

00:43:59,430 --> 00:43:57,760

and this is compare those with rna

1199

00:44:01,670 --> 00:43:59,440

molecules and so forth

1200

00:44:04,470 --> 00:44:01,680

and you can see that already there's uh

1201

00:44:07,109 --> 00:44:04,480

work going on uh that has identified

1202

00:44:10,710 --> 00:44:07,119

uracil and xanthine with

1203

00:44:12,710 --> 00:44:10,720

excesses of carbon 13 by about 38 to 45

1204

00:44:15,109 --> 00:44:12,720

parts per mil

1205

00:44:16,069 --> 00:44:15,119

and you can uh see

1206

00:44:19,430 --> 00:44:16,079

earlier

1207

00:44:20,870 --> 00:44:19,440

work was published by zeta martins and

1208

00:44:22,390 --> 00:44:20,880

collaborators here

1209

00:44:25,270 --> 00:44:22,400

anna carnegie

1210

00:44:27,030 --> 00:44:25,280

through marilyn douglas group

1211

00:44:29,190 --> 00:44:27,040

in that i think she's involved in that

1212

00:44:31,349 --> 00:44:29,200

paper as well

1213

00:44:33,589 --> 00:44:31,359

now another aspect of this lab is to

1214

00:44:36,710 --> 00:44:33,599

look at the complex organics and

1215

00:44:38,630 --> 00:44:36,720

extraterrestrial analogs and

1216

00:44:40,790 --> 00:44:38,640

of course many of you your teams are

1217

00:44:43,430 --> 00:44:40,800

involved in the asap program which danny

1218

00:44:45,349 --> 00:44:43,440

glavin coordinated and led

1219

00:44:46,950 --> 00:44:45,359

so some of that work is uh

1220

00:44:48,950 --> 00:44:46,960

reflected in the public

1221

00:44:51,990 --> 00:44:48,960

that came out of this lab

1222

00:44:54,550 --> 00:44:52,000

uh also looking at some uh work samples

1223

00:44:56,790 --> 00:44:54,560

returned by jen eigenbrod

1224

00:44:58,630 --> 00:44:56,800

from her uh

1225

00:45:00,870 --> 00:44:58,640

the latest valbard expedition she

1226

00:45:02,710 --> 00:45:00,880

collected certain ice samples

1227

00:45:04,390 --> 00:45:02,720

uh and those are being analyzed here

1228

00:45:06,069 --> 00:45:04,400

plus something out of common desert and

1229

00:45:08,710 --> 00:45:06,079

so forth again amino acids and

1230

00:45:10,710 --> 00:45:08,720

nucleobases and so forth and so on

1231

00:45:13,430 --> 00:45:10,720

and finally uh

1232

00:45:16,309 --> 00:45:13,440

analysis of amino acids from the

1233

00:45:19,430 --> 00:45:16,319

historical the residue left from stanley

1234

00:45:21,270 --> 00:45:19,440

miller's historical

1235

00:45:23,190 --> 00:45:21,280

spark discharge experiments which was

1236

00:45:25,510 --> 00:45:23,200

published recently

1237

00:45:28,230 --> 00:45:25,520

and which many of you have undoubtedly

1238

00:45:32,069 --> 00:45:29,910

something new that's going on is this

1239

00:45:34,470 --> 00:45:32,079

development of nanoflow liquid

1240

00:45:35,990 --> 00:45:34,480

chromatographic analysis for

1241

00:45:37,109 --> 00:45:36,000

trace detection

1242

00:45:39,190 --> 00:45:37,119

there's a little sketch of the

1243

00:45:42,230 --> 00:45:39,200

instrument in the upper left

1244

00:45:44,069 --> 00:45:42,240

is rather specialized and so not of

1245

00:45:45,030 --> 00:45:44,079

interest to most people in the institute

1246

00:45:46,710 --> 00:45:45,040

but

1247

00:45:48,309 --> 00:45:46,720

perhaps three of the instrument teams

1248

00:45:49,670 --> 00:45:48,319

doing this kind of work will find this

1249

00:45:50,870 --> 00:45:49,680

interesting i encourage you to look at

1250

00:45:54,309 --> 00:45:50,880

this uh

1251
00:45:55,750 --> 00:45:54,319
in greater detail on on the uh published

1252
00:45:57,910 --> 00:45:55,760
powerpoint uh

1253
00:46:00,069 --> 00:45:57,920
presentation but on the right for

1254
00:46:03,589 --> 00:46:00,079
everyone else just note that

1255
00:46:06,550 --> 00:46:03,599
the standard analysis of this particular

1256
00:46:07,510 --> 00:46:06,560
amino isobutyric acid at 10 minus 15

1257
00:46:10,790 --> 00:46:07,520
level

1258
00:46:13,030 --> 00:46:10,800
shows a very weak peak at this position

1259
00:46:14,870 --> 00:46:13,040
but with this new nanoflow analysis you

1260
00:46:16,790 --> 00:46:14,880
can then see that the same

1261
00:46:20,470 --> 00:46:16,800
uh

1262
00:46:22,790 --> 00:46:20,480
material

1263
00:46:24,630 --> 00:46:22,800

shows a much stronger and far a better

1264

00:46:26,150 --> 00:46:24,640

signal noise ratio on this peak and

1265

00:46:27,430 --> 00:46:26,160

therefore is showing much higher

1266

00:46:29,349 --> 00:46:27,440

sensitivity

1267

00:46:32,069 --> 00:46:29,359

so this uh this is actually quite uh

1268

00:46:34,069 --> 00:46:32,079

exciting because it demonstrates that uh

1269

00:46:37,990 --> 00:46:34,079

sensitivity by this approach is

1270

00:46:42,630 --> 00:46:40,630

let's move on to uh the second uh well

1271

00:46:44,390 --> 00:46:42,640

really the third class of uh ground

1272

00:46:45,750 --> 00:46:44,400

truths which i would say are

1273

00:46:47,829 --> 00:46:45,760

lunar samples

1274

00:46:49,349 --> 00:46:47,839

and these are actually uh rich walker

1275

00:46:51,430 --> 00:46:49,359

mccoys at the university of maryland and

1276

00:46:55,190 --> 00:46:51,440

the geosciences department

1277

00:46:57,750 --> 00:46:55,200

is uh actually pursuing this line of

1278

00:46:59,030 --> 00:46:57,760

evidence on under gca funding through

1279

00:47:00,950 --> 00:46:59,040

nai

1280

00:47:02,870 --> 00:47:00,960

uh what they're really doing is they

1281

00:47:05,589 --> 00:47:02,880

basically are after this question of

1282

00:47:07,589 --> 00:47:05,599

masses compositions and timing

1283

00:47:09,829 --> 00:47:07,599

of material added to the earth moon

1284

00:47:11,190 --> 00:47:09,839

system late on so this goes back and

1285

00:47:13,109 --> 00:47:11,200

relates to the

1286

00:47:15,109 --> 00:47:13,119

if you like the depletion of the

1287

00:47:16,950 --> 00:47:15,119

asteroid belt primitive asteroid belt

1288

00:47:18,230 --> 00:47:16,960

that was mentioned when i discussed how

1289

00:47:20,630 --> 00:47:18,240

levison's

1290

00:47:22,069 --> 00:47:20,640

work in the with the nice model

1291

00:47:24,150 --> 00:47:22,079

and so

1292

00:47:26,470 --> 00:47:24,160

the issue of what was delivered at that

1293

00:47:28,150 --> 00:47:26,480

time they come only from asteroids and

1294

00:47:29,589 --> 00:47:28,160

some come from the outer disk and so

1295

00:47:31,349 --> 00:47:29,599

forth and so on

1296

00:47:33,030 --> 00:47:31,359

is a keen interest we'd like to know

1297

00:47:35,910 --> 00:47:33,040

whether they also brought organic

1298

00:47:37,430 --> 00:47:35,920

molecules to the earth do any survive

1299

00:47:40,309 --> 00:47:37,440

on the moon uh that would have been

1300

00:47:42,309 --> 00:47:40,319

delivered at the same time

1301

00:47:44,950 --> 00:47:42,319

so the methodology is fairly well

1302

00:47:47,349 --> 00:47:44,960

understood you basically crunch

1303

00:47:49,750 --> 00:47:47,359

a precious sample and then carefully

1304

00:47:50,710 --> 00:47:49,760

painstakingly pick out the pieces of

1305

00:47:54,309 --> 00:47:50,720

interest

1306

00:47:55,829 --> 00:47:54,319

and then begin to look at those uh by

1307

00:47:58,230 --> 00:47:55,839

doing these uh determining their

1308

00:48:00,150 --> 00:47:58,240

elemental and isotopic ratios and these

1309

00:48:01,910 --> 00:48:00,160

individual rocks

1310

00:48:03,829 --> 00:48:01,920

and so here's an example on the right

1311

00:48:05,109 --> 00:48:03,839

chart of this classes of data that were

1312

00:48:07,670 --> 00:48:05,119

determined by

1313

00:48:09,430 --> 00:48:07,680

igor putchtel who was supported by gca

1314

00:48:11,829 --> 00:48:09,440

funds

1315

00:48:13,990 --> 00:48:11,839

working on these samples with rich

1316

00:48:17,270 --> 00:48:14,000

and what you can see is that for a given

1317

00:48:18,630 --> 00:48:17,280

sample you get specific ratios but as

1318

00:48:20,550 --> 00:48:18,640

you go to

1319

00:48:22,630 --> 00:48:20,560

additional ones then you develop a slope

1320

00:48:24,630 --> 00:48:22,640

a mixing line if you like

1321

00:48:27,510 --> 00:48:24,640

which gives you the slope of which by

1322

00:48:29,990 --> 00:48:27,520

comparison then gives you the ratios

1323

00:48:31,510 --> 00:48:30,000

of the various elements in these

1324

00:48:34,309 --> 00:48:31,520

particular

1325

00:48:35,510 --> 00:48:34,319

group of samples so in this case showing

1326

00:48:39,030 --> 00:48:35,520

iridium

1327

00:48:40,630 --> 00:48:39,040

versus these other compounds

1328

00:48:43,030 --> 00:48:40,640

then once you have that you can then

1329

00:48:44,630 --> 00:48:43,040

compare those with primitive meteorites

1330

00:48:47,109 --> 00:48:44,640

here for example is

1331

00:48:48,630 --> 00:48:47,119

another measure of the osmium isotopic

1332

00:48:50,790 --> 00:48:48,640

ratios for

1333

00:48:53,109 --> 00:48:50,800

carbonaceous versus ordinary and then

1334

00:48:55,990 --> 00:48:53,119

static chondrites on the left

1335

00:48:58,549 --> 00:48:56,000

and then the primitive earth primitive

1336

00:49:00,790 --> 00:48:58,559

earth mantle shown here and what you see

1337

00:49:03,670 --> 00:49:00,800

is the apollo samples have a range of

1338

00:49:06,069 --> 00:49:03,680

values that represent different classes

1339

00:49:08,630 --> 00:49:06,079

of impacting bodies

1340

00:49:10,630 --> 00:49:08,640

uh there's an issue though as to what is

1341

00:49:13,030 --> 00:49:10,640

uh the what's the implication of these

1342

00:49:14,230 --> 00:49:13,040

non-zero intercepts down here

1343

00:49:16,309 --> 00:49:14,240

because if

1344

00:49:17,829 --> 00:49:16,319

if the feedstock were only at one type

1345

00:49:18,870 --> 00:49:17,839

they should all go through zero you

1346

00:49:21,430 --> 00:49:18,880

would think

1347

00:49:22,549 --> 00:49:21,440

and so the non-zero intercept is being

1348

00:49:24,950 --> 00:49:22,559

pursued

1349

00:49:25,990 --> 00:49:24,960

present time as possible evidence for a

1350

00:49:27,190 --> 00:49:26,000

second

1351
00:49:28,790 --> 00:49:27,200
impactor

1352
00:49:30,549 --> 00:49:28,800
and one way of doing that is to look at

1353
00:49:36,549 --> 00:49:30,559
pristine lunar rocks

1354
00:49:40,309 --> 00:49:37,589
spikes

1355
00:49:42,309 --> 00:49:40,319
these other any uh contributions of

1356
00:49:43,349 --> 00:49:42,319
another impactor in them

1357
00:49:46,069 --> 00:49:43,359
uh

1358
00:49:47,910 --> 00:49:46,079
these are hsc is just highly siderophile

1359
00:49:49,910 --> 00:49:47,920
elements a fancy word for those of you

1360
00:49:53,510 --> 00:49:49,920
who don't work in this field

1361
00:49:53,520 --> 00:49:56,710
the uh

1362
00:50:01,270 --> 00:49:59,109
it shouldn't be here

1363
00:50:02,790 --> 00:50:01,280

uh in any case uh so

1364

00:50:05,109 --> 00:50:02,800

you're going along and trying to figure

1365

00:50:06,470 --> 00:50:05,119

all this out and uh

1366

00:50:08,470 --> 00:50:06,480

that is the next step which will be

1367

00:50:10,390 --> 00:50:08,480

pursued in the next few years under gca

1368

00:50:12,470 --> 00:50:10,400

funding

1369

00:50:15,109 --> 00:50:12,480

now let's move on to uh

1370

00:50:17,270 --> 00:50:15,119

not the ground truths uh provided by

1371

00:50:19,910 --> 00:50:17,280

natural samples but uh

1372

00:50:21,349 --> 00:50:19,920

by uh the study of processes in the

1373

00:50:23,670 --> 00:50:21,359

laboratory

1374

00:50:26,549 --> 00:50:23,680

that could be analogs for

1375

00:50:28,309 --> 00:50:26,559

uh radiation processing of cosmic ices

1376

00:50:31,670 --> 00:50:28,319

on the first

1377

00:50:33,030 --> 00:50:31,680

instance or a cosmic or

1378

00:50:35,270 --> 00:50:33,040

things we're learning about dust

1379

00:50:37,750 --> 00:50:35,280

formation and organics

1380

00:50:39,349 --> 00:50:37,760

related to dust in the second instance

1381

00:50:41,349 --> 00:50:39,359

so first the lab

1382

00:50:43,109 --> 00:50:41,359

headed by marla moore now reggie hudson

1383

00:50:45,270 --> 00:50:43,119

who's been a co-i for many years is now

1384

00:50:47,990 --> 00:50:45,280

here at goddard as a civil servant

1385

00:50:51,510 --> 00:50:48,000

uh john peters and fabianez probably

1386

00:50:53,109 --> 00:50:51,520

working both here with marlon also with

1387

00:50:55,430 --> 00:50:53,119

lee mundy at the university of maryland

1388

00:50:58,790 --> 00:50:55,440

on uh

1389

00:51:01,349 --> 00:50:58,800

material and particularly acetylene and

1390

00:51:03,829 --> 00:51:01,359

disks around the young stars so claudia

1391

00:51:05,270 --> 00:51:03,839

now bridges the laboratory work here at

1392

00:51:07,510 --> 00:51:05,280

goddard with the some of the

1393

00:51:09,030 --> 00:51:07,520

observational work going on at uh

1394

00:51:11,349 --> 00:51:09,040

at maryland

1395

00:51:15,349 --> 00:51:11,359

and zahn of course is a former student

1396

00:51:17,670 --> 00:51:15,359

of uh moscow aaron friends uh at uh

1397

00:51:20,870 --> 00:51:17,680

uh leiden who is uh now associated with

1398

00:51:23,109 --> 00:51:20,880

the wisconsin team and also ours but uh

1399

00:51:24,549 --> 00:51:23,119

it's actually here at george washington

1400

00:51:26,870 --> 00:51:24,559

university

1401
00:51:29,270 --> 00:51:26,880
in washington area

1402
00:51:30,630 --> 00:51:29,280
okay so basically uh what's what we have

1403
00:51:33,109 --> 00:51:30,640
here is a

1404
00:51:34,950 --> 00:51:33,119
unique facility at goddard which has a

1405
00:51:38,309 --> 00:51:34,960
proton accelerator

1406
00:51:40,710 --> 00:51:38,319
uh and marla and uh is able to direct a

1407
00:51:43,589 --> 00:51:40,720
2 mev proton beam

1408
00:51:45,510 --> 00:51:43,599
into a sample chamber in which she has

1409
00:51:48,870 --> 00:51:45,520
deposited

1410
00:51:50,710 --> 00:51:48,880
mixtures of pure ices at

1411
00:51:52,069 --> 00:51:50,720
a specific low temperature

1412
00:51:54,150 --> 00:51:52,079
typically a starting temperature on the

1413
00:51:55,589 --> 00:51:54,160

order of a few tens of kelvin

1414

00:51:57,430 --> 00:51:55,599

she can then

1415

00:52:00,069 --> 00:51:57,440

choose to irradiate that with a proton

1416

00:52:02,870 --> 00:52:00,079

beam or with a kilovolt electron beam to

1417

00:52:05,510 --> 00:52:02,880

simulate x-ray processing or with uv

1418

00:52:07,990 --> 00:52:05,520

photons to simulate uv processing so any

1419

00:52:10,150 --> 00:52:08,000

one of these can be dealt with

1420

00:52:11,910 --> 00:52:10,160

in order to try to

1421

00:52:16,710 --> 00:52:11,920

separate the kinds of

1422

00:52:20,630 --> 00:52:19,510

let's say complex organics of one type

1423

00:52:23,349 --> 00:52:20,640

or another

1424

00:52:25,030 --> 00:52:23,359

so let's look at some examples

1425

00:52:27,349 --> 00:52:25,040

one of the most exciting things that's

1426

00:52:29,030 --> 00:52:27,359

happened recently is that this this a

1427

00:52:31,670 --> 00:52:29,040

here is a picture of the feedstock and

1428

00:52:33,670 --> 00:52:31,680

her apparatus you can see kind of a

1429

00:52:36,630 --> 00:52:33,680

brownish coating

1430

00:52:38,549 --> 00:52:36,640

left on this feedstock after she's

1431

00:52:42,230 --> 00:52:38,559

finished irradiating that she's

1432

00:52:44,150 --> 00:52:42,240

vaporized any processed dices that have

1433

00:52:46,470 --> 00:52:44,160

been formed and analyzed those both

1434

00:52:48,950 --> 00:52:46,480

first to virus absorption spectroscopy

1435

00:52:49,910 --> 00:52:48,960

then after vaporization with gcms and so

1436

00:52:51,750 --> 00:52:49,920

on

1437

00:52:53,910 --> 00:52:51,760

but now what has frustrated people in

1438

00:52:55,510 --> 00:52:53,920

the past was not being able to analyze

1439

00:52:57,829 --> 00:52:55,520

the residue

1440

00:53:00,549 --> 00:52:57,839

uh that has now changed and so what

1441

00:53:03,109 --> 00:53:00,559

happens now is she uh

1442

00:53:05,750 --> 00:53:03,119

reduces this provides a scrapings of

1443

00:53:07,670 --> 00:53:05,760

this residue an aliquot is uh formed

1444

00:53:09,990 --> 00:53:07,680

it's passed through the organic the

1445

00:53:11,030 --> 00:53:10,000

astrobiology analytical

1446

00:53:15,430 --> 00:53:11,040

uh

1447

00:53:17,109 --> 00:53:15,440

and the actual materials identified in

1448

00:53:18,549 --> 00:53:17,119

that are identified

1449

00:53:20,390 --> 00:53:18,559

and this has actually produced some very

1450

00:53:22,390 --> 00:53:20,400

very exciting results

1451

00:53:24,470 --> 00:53:22,400

uh in particular

1452

00:53:27,349 --> 00:53:24,480

uh one of the key things is that it's

1453

00:53:29,910 --> 00:53:27,359

shown that there was in fact a rich

1454

00:53:30,950 --> 00:53:29,920

array of amino acids c5 amino acids for

1455

00:53:33,270 --> 00:53:30,960

example

1456

00:53:34,390 --> 00:53:33,280

are formed in these residues identified

1457

00:53:36,950 --> 00:53:34,400

by

1458

00:53:39,510 --> 00:53:36,960

jason as collaborators in their lab

1459

00:53:42,150 --> 00:53:39,520

but to the great surprise there was a

1460

00:53:43,750 --> 00:53:42,160

great excess in life surveilling over d

1461

00:53:46,150 --> 00:53:43,760

isovalene

1462

00:53:47,750 --> 00:53:46,160

once this was actually looked at more

1463

00:53:50,349 --> 00:53:47,760

carefully it was then realized that

1464

00:53:52,309 --> 00:53:50,359

there was an eluding compound this three

1465

00:53:53,990 --> 00:53:52,319

aminopentanoic acid

1466

00:53:57,190 --> 00:53:54,000

which was coming off at the same time as

1467

00:53:59,109 --> 00:53:57,200

the el isovalene and actually giving

1468

00:54:02,950 --> 00:53:59,119

rise to a

1469

00:54:04,630 --> 00:54:02,960

spurious excess here but even so uh

1470

00:54:06,309 --> 00:54:04,640

once that has been done the excess does

1471

00:54:09,750 --> 00:54:06,319

remain in the case of the merchant

1472

00:54:12,790 --> 00:54:09,760

meteorite and so forth all as well

1473

00:54:14,710 --> 00:54:12,800

now not being content with uh doing uh

1474

00:54:16,710 --> 00:54:14,720

first-line work on

1475

00:54:19,030 --> 00:54:16,720

processing of isis that might find their

1476

00:54:20,710 --> 00:54:19,040

ways into comets

1477

00:54:22,630 --> 00:54:20,720

reggie and marla are also working

1478

00:54:25,349 --> 00:54:22,640

intensely on

1479

00:54:26,790 --> 00:54:25,359

ices that uh could be processed in the

1480

00:54:28,470 --> 00:54:26,800

titan system

1481

00:54:29,589 --> 00:54:28,480

which is uh we all know is one of the

1482

00:54:32,150 --> 00:54:29,599

key uh

1483

00:54:34,549 --> 00:54:32,160

focus groups uh within the uh the icy

1484

00:54:36,710 --> 00:54:34,559

worlds focus group within the nai

1485

00:54:38,950 --> 00:54:36,720

so this work uh is i think uh is going

1486

00:54:40,870 --> 00:54:38,960

on now it's many nitriles are being

1487

00:54:43,589 --> 00:54:40,880

produced along with

1488

00:54:45,829 --> 00:54:43,599

rice amino acids and so forth and this

1489

00:54:48,309 --> 00:54:45,839

is going to be you can have a quick look

1490

00:54:50,069 --> 00:54:48,319

at this by this paper and astrobiology

1491

00:54:51,990 --> 00:54:50,079

in 2008

1492

00:54:53,750 --> 00:54:52,000

but there's much more to come and we

1493

00:54:55,589 --> 00:54:53,760

don't have time to talk about today but

1494

00:54:57,030 --> 00:54:55,599

marla's here in the room and she could

1495

00:55:01,430 --> 00:54:57,040

certainly answer questions for anyone

1496

00:55:03,109 --> 00:55:01,440

who wishes after this uh seminar ends

1497

00:55:05,190 --> 00:55:03,119

all right so i'm gonna we're running out

1498

00:55:07,910 --> 00:55:05,200

of time but of course carl took 15

1499

00:55:10,150 --> 00:55:07,920

minutes to begin with so

1500

00:55:12,230 --> 00:55:10,160

no just teasing but

1501

00:55:14,549 --> 00:55:12,240

the cosmic dust lab

1502

00:55:17,510 --> 00:55:14,559

joe huth has been looking at the issue

1503

00:55:21,829 --> 00:55:17,520

of fisher trump's reactions

1504

00:55:23,910 --> 00:55:21,839

on a dust range that might catalyze

1505

00:55:25,030 --> 00:55:23,920

production organics from co and methane

1506

00:55:27,190 --> 00:55:25,040

in the early

1507

00:55:29,990 --> 00:55:27,200

protoplanetary disk

1508

00:55:31,589 --> 00:55:30,000

and uh to make a long story quite brief

1509

00:55:35,190 --> 00:55:31,599

what he finds is that as soon as you

1510

00:55:36,710 --> 00:55:35,200

make an organic coating on the the grain

1511

00:55:39,190 --> 00:55:36,720

the coating itself becomes a better

1512

00:55:41,589 --> 00:55:39,200

catalyst than the grain was

1513

00:55:43,109 --> 00:55:41,599

no matter what the grain material

1514

00:55:46,309 --> 00:55:43,119

that you started with

1515

00:55:49,589 --> 00:55:46,319

and so these are examples of what they

1516

00:55:52,390 --> 00:55:49,599

do they actually have these long time

1517

00:55:54,390 --> 00:55:52,400

uh sequences where they look at the uh

1518

00:55:57,270 --> 00:55:54,400

build up of this

1519

00:55:57,990 --> 00:55:57,280

organic coating and then the

1520

00:56:01,510 --> 00:55:58,000

the

1521

00:56:02,710 --> 00:56:01,520

chemicals that are produced

1522

00:56:03,510 --> 00:56:02,720

and then that

1523

00:56:05,349 --> 00:56:03,520

is

1524

00:56:07,910 --> 00:56:05,359

shown here that

1525

00:56:10,069 --> 00:56:07,920

as the reaction proceeds basically

1526

00:56:13,109 --> 00:56:10,079

the coating itself is a better catalyst

1527

00:56:15,190 --> 00:56:13,119

initial substrate

1528

00:56:16,549 --> 00:56:15,200

maybe that's not so

1529

00:56:18,069 --> 00:56:16,559

that should have been intuitive in the

1530

00:56:19,750 --> 00:56:18,079

sense that

1531

00:56:22,390 --> 00:56:19,760

in order to have reactions you normally

1532

00:56:24,870 --> 00:56:22,400

have to have hydrogen bonding going on

1533

00:56:26,630 --> 00:56:24,880

initially to hold things there so

1534

00:56:29,829 --> 00:56:26,640

generally

1535

00:56:31,750 --> 00:56:29,839

silicon or magnesium silicates or

1536

00:56:34,309 --> 00:56:31,760

graphite would have

1537

00:56:36,309 --> 00:56:34,319

highly variable bonding but or the

1538

00:56:38,150 --> 00:56:36,319

organic coatings that you've made then

1539

00:56:39,670 --> 00:56:38,160

do have very strong hydrogen bonds and

1540

00:56:41,589 --> 00:56:39,680

so you can hold things more efficiently

1541

00:56:44,309 --> 00:56:41,599

to the surface and so forth

1542

00:56:46,150 --> 00:56:44,319

to catalyze more efficient reactions

1543

00:56:48,870 --> 00:56:46,160

this obviously has

1544

00:56:50,069 --> 00:56:48,880

relevance to outward transport of

1545

00:56:52,309 --> 00:56:50,079

material

1546

00:56:54,390 --> 00:56:52,319

in these organic coatings it may have

1547

00:56:55,670 --> 00:56:54,400

some relevance to other rims seen on

1548

00:56:57,190 --> 00:56:55,680

certain

1549

00:56:58,789 --> 00:56:57,200

elements of meteoritic such as

1550

00:57:00,150 --> 00:56:58,799

chondrules

1551
00:57:01,990 --> 00:57:00,160
it may have other

1552
00:57:04,630 --> 00:57:02,000
implications as well but it does appear

1553
00:57:07,190 --> 00:57:04,640
to be a rather interesting

1554
00:57:08,870 --> 00:57:07,200
finding and probably it will be of

1555
00:57:11,109 --> 00:57:08,880
interest to many other

1556
00:57:13,430 --> 00:57:11,119
members of the nai

1557
00:57:15,349 --> 00:57:13,440
i'll say a few words about other planets

1558
00:57:17,670 --> 00:57:15,359
in our solar system we've touched on

1559
00:57:20,630 --> 00:57:17,680
titan most of what i've said so far has

1560
00:57:22,549 --> 00:57:20,640
to do with delivery of

1561
00:57:23,589 --> 00:57:22,559
organics and water to the terrestrial

1562
00:57:25,190 --> 00:57:23,599
planets

1563
00:57:26,870 --> 00:57:25,200

and so it's important to understand

1564

00:57:28,309 --> 00:57:26,880

whether any other terrestrial planets

1565

00:57:31,750 --> 00:57:28,319

have

1566

00:57:32,950 --> 00:57:31,760

been related to

1567

00:57:33,829 --> 00:57:32,960

the origin of

1568

00:57:36,470 --> 00:57:33,839

life

1569

00:57:38,069 --> 00:57:36,480

or to processes that might mimic uh

1570

00:57:38,870 --> 00:57:38,079

release of materials that could mimic

1571

00:57:40,470 --> 00:57:38,880

the

1572

00:57:42,069 --> 00:57:40,480

biogenesis

1573

00:57:44,309 --> 00:57:42,079

so methylene wires you've heard about

1574

00:57:46,230 --> 00:57:44,319

before i'm not going to dwell on that

1575

00:57:47,990 --> 00:57:46,240

except to remind you of the sources of

1576

00:57:50,789 --> 00:57:48,000

methane on earth that are mainly

1577

00:57:52,630 --> 00:57:50,799

biogenic in origin

1578

00:57:54,870 --> 00:57:52,640

to show you one spectrum which

1579

00:57:57,349 --> 00:57:54,880

demonstrates the detection of water

1580

00:57:59,109 --> 00:57:57,359

lines here here a total of three in this

1581

00:58:01,670 --> 00:57:59,119

case and methane running north to south

1582

00:58:03,990 --> 00:58:01,680

on the planet from lindelin

1583

00:58:05,829 --> 00:58:04,000

the maps that we derive from that uh

1584

00:58:07,589 --> 00:58:05,839

basically this is now from the science

1585

00:58:10,950 --> 00:58:07,599

paper that appeared

1586

00:58:13,670 --> 00:58:10,960

online in january in print in february

1587

00:58:15,510 --> 00:58:13,680

and uh we now see three distinct regions

1588

00:58:17,990 --> 00:58:15,520

of active release that are correlated

1589

00:58:20,150 --> 00:58:18,000

with certain mineralogical signatures

1590

00:58:23,270 --> 00:58:20,160

also from the science paper

1591

00:58:25,589 --> 00:58:23,280

uh and finally that uh what we now are

1592

00:58:27,750 --> 00:58:25,599

preparing our second paper

1593

00:58:29,190 --> 00:58:27,760

uh geronimo's uh we'll be submitting

1594

00:58:31,750 --> 00:58:29,200

that very soon

1595

00:58:34,309 --> 00:58:31,760

and uh here for example we demonstrate

1596

00:58:36,789 --> 00:58:34,319

uh the map of methane from all seasons

1597

00:58:38,390 --> 00:58:36,799

shown here three regions that we showed

1598

00:58:40,710 --> 00:58:38,400

in our first paper

1599

00:58:42,630 --> 00:58:40,720

uh comparing that with water that is

1600

00:58:43,910 --> 00:58:42,640

co-measured in every spectrum with

1601
00:58:46,069 --> 00:58:43,920
methane

1602
00:58:55,349 --> 00:58:46,079
noting that at times we don't see

1603
00:58:58,789 --> 00:58:56,630
he did

1604
00:59:00,309 --> 00:58:58,799
um

1605
00:59:02,309 --> 00:59:00,319
are we back okay

1606
00:59:04,069 --> 00:59:02,319
uh but the key point is whenever we see

1607
00:59:07,430 --> 00:59:04,079
methane being released it's from

1608
00:59:09,109 --> 00:59:07,440
primitive uh terrain milwaukee and being

1609
00:59:10,789 --> 00:59:09,119
uh the first billion years of mars

1610
00:59:12,630 --> 00:59:10,799
history and shown here is this red

1611
00:59:14,309 --> 00:59:12,640
terrain in the southern region so

1612
00:59:16,069 --> 00:59:14,319
there's a lot more to come

1613
00:59:18,390 --> 00:59:16,079

on that story you can read all the

1614

00:59:21,829 --> 00:59:18,400

details and major conclusions

1615

00:59:25,829 --> 00:59:21,839

uh and implications uh when you next

1616

00:59:27,910 --> 00:59:25,839

come back to this in the online material

1617

00:59:29,589 --> 00:59:27,920

now finally i want to conclude with the

1618

00:59:30,950 --> 00:59:29,599

development of

1619

00:59:32,870 --> 00:59:30,960

model the

1620

00:59:35,349 --> 00:59:32,880

techniques for in-situ organic and

1621

00:59:37,349 --> 00:59:35,359

organic analysis on flight missions

1622

00:59:40,150 --> 00:59:37,359

which is a very key uh part of work here

1623

00:59:41,990 --> 00:59:40,160

at goddard through paul mahaffey's team

1624

00:59:44,069 --> 00:59:42,000

which is you know paul is the

1625

00:59:45,829 --> 00:59:44,079

principal investigator on the sam

1626
00:59:48,549 --> 00:59:45,839
instrument on the mars science lab which

1627
00:59:51,030 --> 00:59:48,559
is now scheduled for launch in 2011.

1628
00:59:52,710 --> 00:59:51,040
but that's just one of the many many uh

1629
00:59:54,630 --> 00:59:52,720
parts of the

1630
00:59:57,109 --> 00:59:54,640
activity that this

1631
00:59:59,589 --> 00:59:57,119
group is involved in

1632
01:00:01,510 --> 00:59:59,599
there are actually four separate tasks

1633
01:00:02,630 --> 01:00:01,520
that are being in part supported by the

1634
01:00:05,430 --> 01:00:02,640
gca

1635
01:00:07,910 --> 01:00:05,440
though i must say that uh generally our

1636
01:00:09,990 --> 01:00:07,920
support is modest compared to the total

1637
01:00:11,829 --> 01:00:10,000
costs required to

1638
01:00:14,309 --> 01:00:11,839

pursue these tasks i mean you're talking

1639

01:00:16,789 --> 01:00:14,319

about multiple people and expensive

1640

01:00:19,430 --> 01:00:16,799

equipment and frankly

1641

01:00:21,670 --> 01:00:19,440

this work draws on far larger funding

1642

01:00:22,789 --> 01:00:21,680

resources than we could possibly provide

1643

01:00:25,990 --> 01:00:22,799

through

1644

01:00:27,910 --> 01:00:26,000

any one team at the iii

1645

01:00:29,349 --> 01:00:27,920

uh there are many words in these view

1646

01:00:31,030 --> 01:00:29,359

graphs and so i'm going to skip through

1647

01:00:33,430 --> 01:00:31,040

these very quickly and those of you who

1648

01:00:36,230 --> 01:00:33,440

have great interest can go back and

1649

01:00:37,349 --> 01:00:36,240

re uh review them at uh your your

1650

01:00:40,230 --> 01:00:37,359

leisure

1651
01:00:41,750 --> 01:00:40,240
uh for example just as one uh one case

1652
01:00:44,630 --> 01:00:41,760
here this is

1653
01:00:48,309 --> 01:00:44,640
a sample that was collected by jenna i

1654
01:00:50,710 --> 01:00:48,319
did broad up in svalbard and essentially

1655
01:00:53,670 --> 01:00:50,720
uh the new approach is revealing uh

1656
01:00:56,309 --> 01:00:53,680
three molecular bias signatures that are

1657
01:00:57,829 --> 01:00:56,319
uh that were missed by another common

1658
01:01:00,069 --> 01:00:57,839
method

1659
01:01:02,549 --> 01:01:00,079
we can't talk about these in detail

1660
01:01:04,710 --> 01:01:02,559
right now except the takeaway message is

1661
01:01:06,549 --> 01:01:04,720
that these new methodologies that are

1662
01:01:08,390 --> 01:01:06,559
being developed are in fact more

1663
01:01:10,230 --> 01:01:08,400

powerful and providing additional

1664

01:01:12,630 --> 01:01:10,240

results that were not accessible in

1665

01:01:15,190 --> 01:01:12,640

other ways

1666

01:01:17,030 --> 01:01:15,200

so these are the asap program which many

1667

01:01:18,870 --> 01:01:17,040

of you know about and what's going on

1668

01:01:22,309 --> 01:01:18,880

there and i don't want to repeat that

1669

01:01:23,510 --> 01:01:22,319

you can look at this at your leisure

1670

01:01:25,589 --> 01:01:23,520

one of the key

1671

01:01:28,390 --> 01:01:25,599

areas being developed is by will

1672

01:01:31,190 --> 01:01:28,400

brenkerhoff and his collaborators

1673

01:01:32,230 --> 01:01:31,200

this is a so-called laser desorption

1674

01:01:34,789 --> 01:01:32,240

approach

1675

01:01:36,829 --> 01:01:34,799

instead of cooking uh the sample and

1676

01:01:40,150 --> 01:01:36,839

destroying many thereby destroying many

1677

01:01:42,150 --> 01:01:40,160

organics instead you focus a laser beam

1678

01:01:43,589 --> 01:01:42,160

on a point on the surface and then you

1679

01:01:46,150 --> 01:01:43,599

can vaporize

1680

01:01:48,069 --> 01:01:46,160

that material somewhat less destructive

1681

01:01:50,789 --> 01:01:48,079

but you can then see a wider range of

1682

01:01:52,789 --> 01:01:50,799

heavy organics to much higher dalton

1683

01:01:54,549 --> 01:01:52,799

number or for those of you don't work in

1684

01:01:56,069 --> 01:01:54,559

dalton's atomic mass units than you

1685

01:01:57,910 --> 01:01:56,079

would otherwise see

1686

01:01:59,670 --> 01:01:57,920

and so this is a very uh potentially

1687

01:02:02,069 --> 01:01:59,680

extremely powerful technique that could

1688

01:02:04,470 --> 01:02:02,079

be useful on flight missions to

1689

01:02:06,069 --> 01:02:04,480

comets or to primitive asteroids and so

1690

01:02:07,109 --> 01:02:06,079

forth and so on or even to tighten

1691

01:02:08,789 --> 01:02:07,119

itself

1692

01:02:11,030 --> 01:02:08,799

an example

1693

01:02:14,309 --> 01:02:11,040

is shown here of uh organics produced

1694

01:02:16,230 --> 01:02:14,319

from a uh an analysis of a

1695

01:02:17,910 --> 01:02:16,240

titan following analog produced in the

1696

01:02:20,870 --> 01:02:17,920

laboratory which

1697

01:02:23,990 --> 01:02:20,880

could reveal a polyacetylene

1698

01:02:26,870 --> 01:02:24,000

phase present in the material

1699

01:02:29,270 --> 01:02:26,880

here's a sketch of the instrument

1700

01:02:31,430 --> 01:02:29,280

you can imagine how you raster across

1701

01:02:33,990 --> 01:02:31,440

the surface of a

1702

01:02:35,349 --> 01:02:34,000

section material and then get these uh

1703

01:02:37,270 --> 01:02:35,359

beautiful

1704

01:02:40,309 --> 01:02:37,280

mass spectra in

1705

01:02:45,990 --> 01:02:44,069

now another approach being pursued

1706

01:02:48,390 --> 01:02:46,000

by a number of complementary programs

1707

01:02:49,829 --> 01:02:48,400

has to do with this business of

1708

01:02:51,030 --> 01:02:49,839

carbonation meteorites we've been

1709

01:02:53,349 --> 01:02:51,040

discussing

1710

01:02:55,910 --> 01:02:53,359

looking for signatures of life and ice

1711

01:02:58,630 --> 01:02:55,920

this is funded under exobiology

1712

01:03:00,309 --> 01:02:58,640

uh and so on i can't say too much about

1713

01:03:02,069 --> 01:03:00,319

that now and actually

1714

01:03:05,349 --> 01:03:02,079

we're supporting some some of jen's

1715

01:03:08,710 --> 01:03:05,359

manpower through gca but uh

1716

01:03:09,670 --> 01:03:08,720

as you can appreciate the the overall

1717

01:03:11,910 --> 01:03:09,680

uh

1718

01:03:14,630 --> 01:03:11,920

program involved in paul's group is far

1719

01:03:17,349 --> 01:03:14,640

broader and uh far more expensive than

1720

01:03:19,109 --> 01:03:17,359

uh the nai could possibly support

1721

01:03:22,069 --> 01:03:19,119

and so you see here just a listing of

1722

01:03:24,390 --> 01:03:22,079

some of the other activities and the pis

1723

01:03:27,670 --> 01:03:24,400

and so forth that are going on

1724

01:03:29,750 --> 01:03:27,680

that uh actually benefit the nai by

1725

01:03:32,870 --> 01:03:29,760

essentially we're leveraging these other

1726

01:03:35,190 --> 01:03:32,880

very large and well-funded programs

1727

01:03:38,309 --> 01:03:35,200

and finally just wrap that up by

1728

01:03:40,870 --> 01:03:38,319

pointing to the sample analysis at mars

1729

01:03:43,589 --> 01:03:40,880

here's an example of one of the four

1730

01:03:45,510 --> 01:03:43,599

finalists for the msl landing site

1731

01:03:48,069 --> 01:03:45,520

this is the eevers vaulter created which

1732

01:03:49,029 --> 01:03:48,079

crater which has a well-developed

1733

01:03:52,309 --> 01:03:49,039

delta

1734

01:03:54,950 --> 01:03:52,319

formed over a long period of time and

1735

01:03:56,950 --> 01:03:54,960

suggests that it could have been flowing

1736

01:03:58,710 --> 01:03:56,960

water and

1737

01:04:00,470 --> 01:03:58,720

standing water for quite a long time

1738

01:04:02,069 --> 01:04:00,480

that would permit uh

1739

01:04:03,829 --> 01:04:02,079

organics

1740

01:04:05,190 --> 01:04:03,839

to be formed

1741

01:04:08,150 --> 01:04:05,200

of course everyone would like to know

1742

01:04:10,630 --> 01:04:08,160

they reform biogenically or abiotically

1743

01:04:12,870 --> 01:04:10,640

so i think we'll stop with that

1744

01:04:15,589 --> 01:04:12,880

and uh throw the uh

1745

01:04:19,109 --> 01:04:17,109

throw it open for discussion if anyone

1746

01:04:21,670 --> 01:04:19,119

has any questions let me just go back to

1747

01:04:25,190 --> 01:04:23,190

in case we need to go to a specific

1748

01:04:27,109 --> 01:04:25,200

slide

1749

01:04:34,390 --> 01:04:27,119

okay well let let's first thank our

1750

01:04:38,870 --> 01:04:37,109

thanks for a really information filled

1751

01:04:40,230 --> 01:04:38,880

talk i am sure a lot of people are going

1752

01:04:41,270 --> 01:04:40,240

to be looking at the archive on the

1753

01:04:44,309 --> 01:04:41,280

website

1754

01:04:46,069 --> 01:04:44,319

now i'd like to open up for questions

1755

01:04:47,990 --> 01:04:46,079

right away and i'd like to ask the first

1756

01:04:50,150 --> 01:04:48,000

question i must confess this question

1757

01:04:51,510 --> 01:04:50,160

may be more appropriate for alan boss

1758

01:04:54,390 --> 01:04:51,520

than for you but

1759

01:04:56,470 --> 01:04:54,400

in the nice model you've got the core

1760

01:04:58,230 --> 01:04:56,480

you've got uranus and neptune forming so

1761

01:05:00,630 --> 01:04:58,240

close to saturn

1762

01:05:03,430 --> 01:05:00,640

and so now you have all four major

1763

01:05:05,990 --> 01:05:03,440

planets forming within less than 10 a.u

1764

01:05:08,069 --> 01:05:06,000

you've got 300 earth masses of hydrogen

1765

01:05:10,150 --> 01:05:08,079

and helium and jupiter you've got maybe

1766

01:05:11,829 --> 01:05:10,160

85 in saturn

1767

01:05:13,750 --> 01:05:11,839

and with uranus and neptune forming

1768

01:05:14,549 --> 01:05:13,760

right nearby you've only got one earth

1769

01:05:17,349 --> 01:05:14,559

mass

1770

01:05:18,950 --> 01:05:17,359

of hydrogen and helium on their cores

1771

01:05:20,870 --> 01:05:18,960

how do you get that difference

1772

01:05:23,190 --> 01:05:20,880

particularly between saturn and the

1773

01:05:26,069 --> 01:05:23,200

uranus and neptunes uh when they're

1774

01:05:28,230 --> 01:05:26,079

formed so close to one another

1775

01:05:31,109 --> 01:05:28,240

um well alan if you'd like to answer

1776

01:05:32,710 --> 01:05:31,119

that that's just fine

1777

01:05:35,109 --> 01:05:32,720

let me take a shot

1778

01:05:38,390 --> 01:05:35,119

i'll get my own spin on it later

1779

01:05:39,990 --> 01:05:38,400

okay carl i think what what uh you hit a

1780

01:05:41,670 --> 01:05:40,000

really major question which is the nice

1781

01:05:43,270 --> 01:05:41,680

model is wonderful if you can figure out

1782

01:05:44,549 --> 01:05:43,280

a way to get those initial conditions

1783

01:05:46,470 --> 01:05:44,559

but in some sense those initial

1784

01:05:48,549 --> 01:05:46,480

conditions are like handing somebody a

1785

01:05:50,150 --> 01:05:48,559

tin can with a spring compressed inside

1786

01:05:51,589 --> 01:05:50,160

it and you ask them to open up the the

1787

01:05:52,950 --> 01:05:51,599

lid of the can and the spring pops out

1788

01:05:54,470 --> 01:05:52,960

and the question is how did that spring

1789

01:05:56,710 --> 01:05:54,480

manage to compress itself inside that

1790

01:05:58,789 --> 01:05:56,720

can so in the context of the traditional

1791

01:06:00,309 --> 01:05:58,799

core accretion model making the

1792

01:06:01,829 --> 01:06:00,319

gas giant planets it's a little bit

1793

01:06:03,910 --> 01:06:01,839

harder to imagine doing it because you

1794

01:06:05,430 --> 01:06:03,920

do as you say have to form all four of

1795

01:06:07,270 --> 01:06:05,440

them within a rather small region of

1796

01:06:08,950 --> 01:06:07,280

space and that process by definition

1797

01:06:11,109 --> 01:06:08,960

takes maybe a million years or more for

1798

01:06:12,950 --> 01:06:11,119

core accretion and so it takes a while

1799

01:06:14,150 --> 01:06:12,960

for that uh you can't sort of hard to

1800

01:06:15,670 --> 01:06:14,160

imagine that spring managing getting

1801

01:06:17,029 --> 01:06:15,680

itself inside the can

1802

01:06:18,390 --> 01:06:17,039

i would assert though that the

1803

01:06:19,829 --> 01:06:18,400

alternative which is to try to make the

1804

01:06:21,829 --> 01:06:19,839

gas giants more rapidly by the

1805

01:06:23,589 --> 01:06:21,839

disconstability process

1806

01:06:25,109 --> 01:06:23,599

really is a way of making maybe getting

1807

01:06:27,510 --> 01:06:25,119

that spring in there rather quickly

1808

01:06:29,109 --> 01:06:27,520

because if you can make them fast enough

1809

01:06:30,829 --> 01:06:29,119

and then pull the gas away and let

1810

01:06:32,870 --> 01:06:30,839

things evolve as the nice model

1811

01:06:34,309 --> 01:06:32,880

envisions uh perhaps that's the way to

1812

01:06:35,990 --> 01:06:34,319

get there in fact i mentioned that to

1813

01:06:37,510 --> 01:06:36,000

hal levi sent at a nobel conference a

1814

01:06:38,950 --> 01:06:37,520

couple summers ago and house says well

1815

01:06:40,230 --> 01:06:38,960

let's can you actually do the same sort

1816

01:06:41,589 --> 01:06:40,240

of thing in disco stability i've got

1817

01:06:42,870 --> 01:06:41,599

models running right now on the computer

1818

01:06:44,710 --> 01:06:42,880

that are trying to see what the

1819

01:06:46,789 --> 01:06:44,720

discontinued alternative is but i think

1820

01:06:48,630 --> 01:06:46,799

the basic idea though the nice model is

1821

01:06:50,069 --> 01:06:48,640

sort of working backwards in time say if

1822

01:06:51,990 --> 01:06:50,079

you can somehow get to this intermediate

1823

01:06:53,670 --> 01:06:52,000

stage then things really work out nicely

1824

01:06:55,109 --> 01:06:53,680

to go from there to the present and the

1825

01:06:56,549 --> 01:06:55,119

real question then is for the theorists

1826
01:06:58,630 --> 01:06:56,559
how do you get from the very beginning

1827
01:07:00,150 --> 01:06:58,640
to that stage and that's where uh folks

1828
01:07:02,710 --> 01:07:00,160
like hal everson and i have a lot of

1829
01:07:05,430 --> 01:07:02,720
work to do yet that's it

1830
01:07:09,589 --> 01:07:07,190
thank you that was a nice it was a nice

1831
01:07:13,029 --> 01:07:09,599
uh discussion uh alan

1832
01:07:14,549 --> 01:07:13,039
uh and i i glossed over that first uh as

1833
01:07:16,789 --> 01:07:14,559
you know the first few hundred million

1834
01:07:19,109 --> 01:07:16,799
years when the giant planets form

1835
01:07:20,630 --> 01:07:19,119
i think hal has too

1836
01:07:22,470 --> 01:07:20,640
but uh the key

1837
01:07:25,109 --> 01:07:22,480
in terms of the uh

1838
01:07:27,190 --> 01:07:25,119

creation of the the icy uh planetesimal

1839

01:07:29,589 --> 01:07:27,200

reservoirs and uh

1840

01:07:32,069 --> 01:07:29,599

how we can further constrain the nice

1841

01:07:34,950 --> 01:07:32,079

model by measuring compositions of

1842

01:07:36,630 --> 01:07:34,960

comets d to h ratios and so on we think

1843

01:07:38,630 --> 01:07:36,640

that's the only way one can really make

1844

01:07:40,309 --> 01:07:38,640

progress in further

1845

01:07:42,470 --> 01:07:40,319

understanding the limitations of that

1846

01:07:44,470 --> 01:07:42,480

model or it's successes

1847

01:07:45,910 --> 01:07:44,480

basically uh looking at these ground

1848

01:07:47,750 --> 01:07:45,920

truth uh

1849

01:07:50,150 --> 01:07:47,760

objects and then understanding trying to

1850

01:07:51,990 --> 01:07:50,160

understand what what actually did happen

1851

01:07:54,309 --> 01:07:52,000

uh what region of the planetary disk

1852

01:07:57,270 --> 01:07:54,319

those materials did come

1853

01:07:59,349 --> 01:07:57,280

and then go back and ask okay did we

1854

01:08:01,270 --> 01:07:59,359

start out with those four planets in

1855

01:08:03,829 --> 01:08:01,280

those locations because in the first

1856

01:08:06,069 --> 01:08:03,839

million years they all formed then

1857

01:08:08,549 --> 01:08:06,079

through instabilities or

1858

01:08:09,990 --> 01:08:08,559

at that location or what i i think

1859

01:08:13,349 --> 01:08:10,000

there's a lot of work still to be done

1860

01:08:17,349 --> 01:08:15,990

we have a question here at ames from uh

1861

01:08:19,749 --> 01:08:17,359

dave dimaray

1862

01:08:22,470 --> 01:08:19,759

yeah mike uh it's really fascinating to

1863

01:08:24,709 --> 01:08:22,480

see the comment work and the inference

1864

01:08:27,510 --> 01:08:24,719

maybe of multiple populations emerging

1865

01:08:28,950 --> 01:08:27,520

um what about regular uh or carbonaceous

1866

01:08:30,229 --> 01:08:28,960

chondrites you guys of course are

1867

01:08:32,950 --> 01:08:30,239

involved with the

1868

01:08:35,590 --> 01:08:32,960

analyses of amino acids and stuff in the

1869

01:08:37,030 --> 01:08:35,600

type meteorites any parallel effort that

1870

01:08:38,550 --> 01:08:37,040

might be useful

1871

01:08:40,550 --> 01:08:38,560

well i don't really ought to turn that

1872

01:08:43,269 --> 01:08:40,560

over to jason or danny uh because

1873

01:08:45,189 --> 01:08:43,279

they've been working on that here um i

1874

01:08:47,269 --> 01:08:45,199

don't think they're in the room

1875

01:08:48,870 --> 01:08:47,279

uh but uh if anybody's online they can

1876

01:08:51,669 --> 01:08:48,880

certainly leap in

1877

01:08:53,990 --> 01:08:51,679

uh but in any case uh that is obviously

1878

01:08:56,630 --> 01:08:54,000

one of the things we'd really like to do

1879

01:08:58,229 --> 01:08:56,640

you're certainly well aware dave that uh

1880

01:08:59,269 --> 01:08:58,239

the other example is the stardust

1881

01:09:01,110 --> 01:08:59,279

samples

1882

01:09:03,110 --> 01:09:01,120

which show i think carnegie has shown

1883

01:09:04,630 --> 01:09:03,120

this very nicely to show very strong

1884

01:09:06,550 --> 01:09:04,640

evidence for

1885

01:09:08,470 --> 01:09:06,560

uh dust that's processed in the

1886

01:09:09,749 --> 01:09:08,480

terrestrial planets region and then

1887

01:09:10,470 --> 01:09:09,759

moved outward

1888

01:09:12,309 --> 01:09:10,480

so

1889

01:09:14,070 --> 01:09:12,319

um one of the things i didn't have time

1890

01:09:15,430 --> 01:09:14,080

to address was we're very interested in

1891

01:09:18,070 --> 01:09:15,440

this question of

1892

01:09:20,470 --> 01:09:18,080

what happened before the

1893

01:09:22,470 --> 01:09:20,480

icy bodies and the meteorites the parent

1894

01:09:25,189 --> 01:09:22,480

bodies meteorites formed

1895

01:09:26,149 --> 01:09:25,199

that is to say uh from the natal cloud

1896

01:09:28,309 --> 01:09:26,159

core

1897

01:09:30,709 --> 01:09:28,319

going through the

1898

01:09:32,950 --> 01:09:30,719

protoplanetary disk there was a great

1899

01:09:35,030 --> 01:09:32,960

deal of dynamical mixing going on as

1900

01:09:37,189 --> 01:09:35,040

well as chemical processing

1901

01:09:39,189 --> 01:09:37,199

that preceded the formation of the the

1902

01:09:40,789 --> 01:09:39,199

giant planets and of course the minor

1903

01:09:42,229 --> 01:09:40,799

bodies as well

1904

01:09:44,470 --> 01:09:42,239

so the only way we're ever going to get

1905

01:09:46,309 --> 01:09:44,480

a handle on that is to do just exactly

1906

01:09:48,229 --> 01:09:46,319

what you're suggesting

1907

01:09:50,149 --> 01:09:48,239

namely the uh

1908

01:09:52,149 --> 01:09:50,159

organic composition of individual

1909

01:09:54,470 --> 01:09:52,159

inclusions and meteoritics perimeter

1910

01:09:56,790 --> 01:09:54,480

meteorites in particular the

1911

01:09:59,510 --> 01:09:56,800

uh carbonaceous chondrites uh additional

1912

01:10:01,750 --> 01:09:59,520

comet samples and so forth and so on

1913

01:10:05,189 --> 01:10:01,760

so i think that's uh that that whole

1914

01:10:07,510 --> 01:10:05,199

area of understanding is still

1915

01:10:13,030 --> 01:10:07,520

only sparsely sampled and sparsely

1916

01:10:18,149 --> 01:10:15,669

do we have any other questions for mike

1917

01:10:20,149 --> 01:10:18,159

or for anyone else

1918

01:10:21,270 --> 01:10:20,159

alan is it possible to ask questions by

1919

01:10:24,149 --> 01:10:21,280

phone

1920

01:10:26,070 --> 01:10:24,159

yes absolutely that sounds like max

1921

01:10:30,310 --> 01:10:26,080

you're dead right it is max

1922

01:10:33,669 --> 01:10:30,320

i hope i'm not dead right max but

1923

01:10:35,430 --> 01:10:33,679

um mike uh for just a preface uh

1924

01:10:39,030 --> 01:10:35,440

statement i'm glad i got my tax return

1925

01:10:42,229 --> 01:10:39,040

in early given the time now

1926

01:10:45,350 --> 01:10:42,239

the question i'm asking is is there a

1927

01:10:48,709 --> 01:10:45,360

scope with your method of relating dh

1928

01:10:50,630 --> 01:10:48,719

ratios and volatile ratios

1929

01:10:51,510 --> 01:10:50,640

to differentiate

1930

01:10:55,990 --> 01:10:51,520

the

1931

01:10:57,910 --> 01:10:56,000

delivery and subsequent

1932

01:11:00,470 --> 01:10:57,920

similar fractionation processes on

1933

01:11:04,070 --> 01:11:00,480

planetary surfaces for for loss of

1934

01:11:05,110 --> 01:11:04,080

volatiles like say on earth and on mars

1935

01:11:07,350 --> 01:11:05,120

um

1936

01:11:08,709 --> 01:11:07,360

well let's first talk about the

1937

01:11:11,590 --> 01:11:08,719

um

1938

01:11:14,550 --> 01:11:11,600

the lessons learned from d2h in a

1939

01:11:15,590 --> 01:11:14,560

primitive body whether a comet or an

1940

01:11:17,189 --> 01:11:15,600

asteroid

1941

01:11:19,030 --> 01:11:17,199

i know more about the volatiles and

1942

01:11:20,790 --> 01:11:19,040

comets than i know about asteroids so

1943

01:11:22,149 --> 01:11:20,800

perhaps someone else could address the

1944

01:11:23,350 --> 01:11:22,159

latter question

1945

01:11:25,030 --> 01:11:23,360

but

1946

01:11:26,950 --> 01:11:25,040

as you well know that you probably

1947

01:11:30,870 --> 01:11:26,960

remember max that

1948

01:11:33,350 --> 01:11:30,880

and hal bop uh toby owen uh and his uh

1949

01:11:37,430 --> 01:11:33,360

collaborator postdoc roland meyer

1950

01:11:38,790 --> 01:11:37,440

and others measured uh the ratio of dcn

1951

01:11:43,030 --> 01:11:38,800

to hcn

1952

01:11:45,910 --> 01:11:43,040

and hdo to h2o in the same comet

1953

01:11:48,070 --> 01:11:45,920

and they found that the ratios of the

1954

01:11:51,030 --> 01:11:48,080

enrichment of deuterium in those two

1955

01:11:53,830 --> 01:11:51,040

chemicals was quite different

1956

01:11:54,870 --> 01:11:53,840

and this in fact is predicted if both

1957

01:11:57,590 --> 01:11:54,880

were

1958

01:12:00,229 --> 01:11:57,600

uh influenced by ion molecule processing

1959

01:12:01,910 --> 01:12:00,239

at a temperature of about 30 kelvin

1960

01:12:05,189 --> 01:12:01,920

uh you would then expect

1961

01:12:08,390 --> 01:12:05,199

the uh deuterium content of hcn to be

1962

01:12:10,390 --> 01:12:08,400

much more intense than that in h2o

1963

01:12:12,310 --> 01:12:10,400

so this was in fact their conclusion

1964

01:12:15,030 --> 01:12:12,320

that it was that those ices were

1965

01:12:17,350 --> 01:12:15,040

processed at about 30 kelvin

1966

01:12:19,350 --> 01:12:17,360

that of course then is consistent with

1967

01:12:21,910 --> 01:12:19,360

the modal

1968

01:12:24,709 --> 01:12:21,920

ortho power ratio that we see in most of

1969

01:12:28,229 --> 01:12:24,719

the organic normal comets and hail bop

1970

01:12:29,750 --> 01:12:28,239

was an ornate organic normal comet

1971

01:12:31,430 --> 01:12:29,760

so we think that

1972

01:12:35,350 --> 01:12:31,440

when you consider

1973

01:12:36,870 --> 01:12:35,360

outward convection of or mixing of

1974

01:12:38,229 --> 01:12:36,880

deuterium poor water from the

1975

01:12:39,910 --> 01:12:38,239

terrestrial planets region the

1976

01:12:43,189 --> 01:12:39,920

protoplanetary disk

1977

01:12:44,950 --> 01:12:43,199

to the uh let's say 10 to 30 au region

1978

01:12:47,430 --> 01:12:44,960

uh in the disk

1979

01:12:50,470 --> 01:12:47,440

uh when that water condenses it should

1980

01:12:51,830 --> 01:12:50,480

carry into the newly formed ice

1981

01:12:54,310 --> 01:12:51,840

deuterium

1982

01:12:56,550 --> 01:12:54,320

at a much lower ratio in fact the

1983

01:12:58,390 --> 01:12:56,560

temperature's so high the terrestrial

1984

01:13:01,110 --> 01:12:58,400

planets region that

1985

01:13:02,709 --> 01:13:01,120

the water in that gas phase there

1986

01:13:04,870 --> 01:13:02,719

should achieve equilibrium with

1987

01:13:06,550 --> 01:13:04,880

molecular hydrogen it should have a doh

1988

01:13:07,990 --> 01:13:06,560

ratio of order two times to the minus

1989

01:13:09,110 --> 01:13:08,000

five

1990

01:13:09,910 --> 01:13:09,120

instead of

1991

01:13:11,430 --> 01:13:09,920

uh

1992

01:13:12,310 --> 01:13:11,440

one and a half times ten to the minus

1993

01:13:14,950 --> 01:13:12,320

four

1994

01:13:17,270 --> 01:13:14,960

as in uh terrestrial ocean water or

1995

01:13:19,910 --> 01:13:17,280

three times seven minus five it's four

1996

01:13:21,830 --> 01:13:19,920

excuse me as in hal bot

1997

01:13:24,229 --> 01:13:21,840

so we think that uh

1998

01:13:26,709 --> 01:13:24,239

we don't yet have those numbers for

1999

01:13:28,550 --> 01:13:26,719

the organic depleted comets in hand and

2000

01:13:31,430 --> 01:13:28,560

we think that

2001

01:13:34,550 --> 01:13:31,440

all the comets measured so far

2002

01:13:37,590 --> 01:13:34,560

are the organics normal type

2003

01:13:38,550 --> 01:13:37,600

in the d to h ratio on water and most of

2004

01:13:39,510 --> 01:13:38,560

them

2005

01:13:44,870 --> 01:13:39,520

have

2006

01:13:46,790 --> 01:13:44,880

enrichment factors which agree with one

2007

01:13:47,830 --> 01:13:46,800

another with an experimental error

2008

01:13:50,390 --> 01:13:47,840

though

2009

01:13:52,149 --> 01:13:50,400

one must be careful because

2010

01:13:54,950 --> 01:13:52,159

some of the measurements have very large

2011

01:13:55,830 --> 01:13:54,960

systematic errors for

2012

01:13:57,990 --> 01:13:55,840

proper

2013

01:14:00,790 --> 01:13:58,000

systematic uncertainty

2014

01:14:02,470 --> 01:14:00,800

and these are usually glossed over

2015

01:14:04,870 --> 01:14:02,480

in the literature

2016

01:14:07,990 --> 01:14:04,880

and so uh

2017

01:14:09,270 --> 01:14:08,000

it may be that the agreement so far is

2018

01:14:11,990 --> 01:14:09,280

um

2019

01:14:13,430 --> 01:14:12,000

not a valid reflection of the true

2020

01:14:16,229 --> 01:14:13,440

values

2021

01:14:19,189 --> 01:14:16,239

so i i personally regard this field as

2022

01:14:21,669 --> 01:14:19,199

one that is about to break open

2023

01:14:24,950 --> 01:14:21,679

because we now have

2024

01:14:27,590 --> 01:14:24,960

the ability to measure multiple lines of

2025

01:14:29,189 --> 01:14:27,600

hdo in the infrared

2026

01:14:32,149 --> 01:14:29,199

at the same time that we measured

2027

01:14:35,430 --> 01:14:32,159

multiple lines of h₂o in the same object

2028

01:14:37,510 --> 01:14:35,440

i mean the same time in the same

2029

01:14:39,030 --> 01:14:37,520

spectrum with a cross disperse to shell

2030

01:14:43,030 --> 01:14:39,040

spectrometer

2031

01:14:44,950 --> 01:14:43,040

and this will eliminate uncertainties as

2032

01:14:46,950 --> 01:14:44,960

to whether the rotational temperatures

2033

01:14:48,709 --> 01:14:46,960

of the molecules are the same

2034

01:14:51,030 --> 01:14:48,719

and therefore whether you are

2035

01:14:52,149 --> 01:14:51,040

estimating the total population

2036

01:14:54,070 --> 01:14:52,159

correctly

2037

01:14:55,990 --> 01:14:54,080

it will eliminate all kinds of

2038

01:14:57,669 --> 01:14:56,000

uncertainties with respect to the

2039

01:14:59,750 --> 01:14:57,679

observing conditions

2040

01:15:01,590 --> 01:14:59,760

and so on and so i think this is how we

2041

01:15:05,030 --> 01:15:01,600

will build a

2042

01:15:06,790 --> 01:15:05,040

uh very robust and very reliable

2043

01:15:08,229 --> 01:15:06,800

uh

2044

01:15:11,030 --> 01:15:08,239

database for

2045

01:15:13,350 --> 01:15:11,040

iteration fractions and comets that

2046

01:15:15,110 --> 01:15:13,360

have most systematic errors removed from

2047

01:15:16,709 --> 01:15:15,120

the data

2048

01:15:19,110 --> 01:15:16,719

now as far as the meteoritics are

2049

01:15:20,870 --> 01:15:19,120

concerned uh oh actually let me go to

2050

01:15:24,790 --> 01:15:20,880

the second aspect of your question which

2051

01:15:27,430 --> 01:15:24,800

was the planetary enrichment factors

2052

01:15:29,510 --> 01:15:27,440

uh primitive planets uh like the young

2053

01:15:32,229 --> 01:15:29,520

earth can experience a blow off of their

2054

01:15:34,229 --> 01:15:32,239

early atmospheres hydrodynamic blow-off

2055

01:15:35,990 --> 01:15:34,239

this has been i passed uh examined by

2056

01:15:38,870 --> 01:15:36,000

peplin and

2057

01:15:40,070 --> 01:15:38,880

haunted and other early workers uh 20 30

2058

01:15:41,750 --> 01:15:40,080

years ago

2059

01:15:44,870 --> 01:15:41,760

uh who showed that you could in fact

2060

01:15:46,709 --> 01:15:44,880

produce enriched deuterium in this way

2061

01:15:49,430 --> 01:15:46,719

uh on earth

2062

01:15:52,470 --> 01:15:49,440

on the other hand we don't know

2063

01:15:54,229 --> 01:15:52,480

uh how much water how much more

2064

01:15:56,709 --> 01:15:54,239

correctly how much hydrogen is

2065

01:15:58,950 --> 01:15:56,719

sequestered in the core

2066

01:16:01,669 --> 01:15:58,960

and as you know at the uh the workshop

2067

01:16:04,070 --> 01:16:01,679

in molokai sponsored by nai and

2068

01:16:06,390 --> 01:16:04,080

organized by karen meach's team

2069

01:16:08,470 --> 01:16:06,400

uh we had 30 people who uh examined all

2070

01:16:10,070 --> 01:16:08,480

aspects of this question and

2071

01:16:12,149 --> 01:16:10,080

the simple

2072

01:16:15,110 --> 01:16:12,159

answer is you could have as much as

2073

01:16:17,510 --> 01:16:15,120

seven to 100 oceans of water equivalent

2074

01:16:18,310 --> 01:16:17,520

hydrogen sequestered in the core

2075

01:16:21,510 --> 01:16:18,320

but

2076
01:16:23,910 --> 01:16:21,520
in doing so it's likely that deuterium

2077
01:16:25,669 --> 01:16:23,920
was fractionated

2078
01:16:26,550 --> 01:16:25,679
uh and therefore

2079
01:16:28,149 --> 01:16:26,560
some

2080
01:16:30,550 --> 01:16:28,159
uh fraction of the enrichment in

2081
01:16:31,910 --> 01:16:30,560
terrestrial ocean water could be uh the

2082
01:16:35,430 --> 01:16:31,920
signature of

2083
01:16:37,350 --> 01:16:35,440
in part of that process so

2084
01:16:39,590 --> 01:16:37,360
when you say we're going to get the doh

2085
01:16:42,550 --> 01:16:39,600
ratio and classes of comets we're going

2086
01:16:45,510 --> 01:16:42,560
to identify whether depleted organic

2087
01:16:47,669 --> 01:16:45,520
comets have low doh and therefore

2088
01:16:48,630 --> 01:16:47,679

and formation temperatures that suggest

2089

01:16:55,110 --> 01:16:48,640

uh

2090

01:16:57,750 --> 01:16:55,120

to 10au region versus other enriched

2091

01:17:00,390 --> 01:16:57,760

uh comets in deterrant and organics that

2092

01:17:02,870 --> 01:17:00,400

form from legacy ices further out

2093

01:17:05,830 --> 01:17:02,880

even that will not be a full answer we

2094

01:17:09,189 --> 01:17:05,840

still must pursue the issue of what

2095

01:17:12,390 --> 01:17:09,199

happened uh when the earth moon system

2096

01:17:14,550 --> 01:17:12,400

uh evolved and how did the

2097

01:17:16,630 --> 01:17:14,560

expression of hydrogen from the deep

2098

01:17:18,709 --> 01:17:16,640

earth

2099

01:17:20,709 --> 01:17:18,719

reveal itself in the form of deuteration

2100

01:17:22,470 --> 01:17:20,719

in the water that we now see in earth's

2101
01:17:24,709 --> 01:17:22,480
oceans

2102
01:17:26,709 --> 01:17:24,719
i think i should stop there

2103
01:17:31,350 --> 01:17:26,719
suggest maybe we have other discourse

2104
01:17:36,229 --> 01:17:33,750
thanks mike at the risk of causing some

2105
01:17:38,390 --> 01:17:36,239
of you to file for tax extensions i'll

2106
01:17:39,830 --> 01:17:38,400
call on alan boss i believe he had a

2107
01:17:41,590 --> 01:17:39,840
question

2108
01:17:43,510 --> 01:17:41,600
yeah i'll make a quick a comment and a

2109
01:17:45,430 --> 01:17:43,520
question this the comment first is to uh

2110
01:17:47,350 --> 01:17:45,440
thank you carl for organizing a series

2111
01:17:49,270 --> 01:17:47,360
of uh team presentations because i think

2112
01:17:50,950 --> 01:17:49,280
they're very valuable for allowing all

2113
01:17:52,630 --> 01:17:50,960

of us to see across the whole institute

2114

01:17:53,510 --> 01:17:52,640

what's going on i've only seen a couple

2115

01:17:54,950 --> 01:17:53,520

of them because i've been a lot of

2116

01:17:56,310 --> 01:17:54,960

travel lately but the two i've seen this

2117

01:17:58,149 --> 01:17:56,320

week are really quite valuable so i'm

2118

01:18:00,229 --> 01:17:58,159

looking forward to seeing more question

2119

01:18:02,550 --> 01:18:00,239

for michael

2120

01:18:03,990 --> 01:18:02,560

do check the art do check the archive

2121

01:18:04,790 --> 01:18:04,000

they're all up there you can see them

2122

01:18:07,189 --> 01:18:04,800

all

2123

01:18:09,030 --> 01:18:07,199

okay thanks carl question for michael

2124

01:18:10,790 --> 01:18:09,040

has to do with um uh when you're talking

2125

01:18:12,709 --> 01:18:10,800

about the nuclear spin temperatures and

2126
01:18:13,669 --> 01:18:12,719
the earth apparel ratios and things with

2127
01:18:15,669 --> 01:18:13,679
very low

2128
01:18:17,669 --> 01:18:15,679
really nice low temperatures 20 30 40

2129
01:18:19,350 --> 01:18:17,679
degrees kelvin or so question is

2130
01:18:21,270 --> 01:18:19,360
presumably those are being measured by

2131
01:18:23,270 --> 01:18:21,280
molecules being sublimated off the

2132
01:18:24,390 --> 01:18:23,280
surfaces of comets

2133
01:18:26,149 --> 01:18:24,400
and the

2134
01:18:27,189 --> 01:18:26,159
i guess the kinetic temperatures are

2135
01:18:29,430 --> 01:18:27,199
actually quite a bit higher than that

2136
01:18:30,630 --> 01:18:29,440
when they're being sublimated so is

2137
01:18:32,229 --> 01:18:30,640
there a question that's made for that or

2138
01:18:33,750 --> 01:18:32,239

how do you how do you look at a rather

2139

01:18:35,750 --> 01:18:33,760

higher temperature species and infer a

2140

01:18:37,430 --> 01:18:35,760

lower temperature i just technical

2141

01:18:39,030 --> 01:18:37,440

question just how it's done

2142

01:18:41,350 --> 01:18:39,040

oh right

2143

01:18:42,790 --> 01:18:41,360

i actually published a paper in 1987

2144

01:18:44,870 --> 01:18:42,800

which after the

2145

01:18:47,189 --> 01:18:44,880

comet halley campaigns that laid out the

2146

01:18:48,950 --> 01:18:47,199

methodology for that it appears as

2147

01:18:50,310 --> 01:18:48,960

astronomy and astrophysics

2148

01:18:52,310 --> 01:18:50,320

and that was the first comment for which

2149

01:18:55,030 --> 01:18:52,320

we got such measurements

2150

01:18:57,350 --> 01:18:55,040

that showed a relaxed opr and the spin

2151

01:19:00,390 --> 01:18:57,360

temperature of about 35 kelvin

2152

01:19:04,229 --> 01:19:00,400

but in any case what we do is uh we now

2153

01:19:05,510 --> 01:19:04,239

measure uh up to several dozen lines of

2154

01:19:09,350 --> 01:19:05,520

water vapor

2155

01:19:10,709 --> 01:19:09,360

uh simultaneously using the capcor nurse

2156

01:19:12,229 --> 01:19:10,719

blt

2157

01:19:14,149 --> 01:19:12,239

uh high dispersion infrared

2158

01:19:16,950 --> 01:19:14,159

spectrometers

2159

01:19:18,470 --> 01:19:16,960

and these uh we then

2160

01:19:20,630 --> 01:19:18,480

use those to

2161

01:19:23,270 --> 01:19:20,640

compare with a model a fluorescence

2162

01:19:25,910 --> 01:19:23,280

model for the ortho ladder separately

2163

01:19:28,229 --> 01:19:25,920

from the one of the para ladder and that

2164

01:19:29,990 --> 01:19:28,239

gives us the populations of those two

2165

01:19:31,990 --> 01:19:30,000

spin species

2166

01:19:32,790 --> 01:19:32,000

it turns out that the lowest level in

2167

01:19:36,149 --> 01:19:32,800

the

2168

01:19:36,870 --> 01:19:36,159

ortholateral has an energy that's about

2169

01:19:45,750 --> 01:19:36,880

uh

2170

01:19:48,550 --> 01:19:45,760

the ground level which is in the para

2171

01:19:51,590 --> 01:19:48,560

ladder and so you can apply a boltzmann

2172

01:19:53,830 --> 01:19:51,600

uh like term to that to extract the

2173

01:19:55,750 --> 01:19:53,840

effective spin temperature that is

2174

01:19:57,110 --> 01:19:55,760

required to explain the observed

2175

01:19:59,030 --> 01:19:57,120

distribution

2176

01:20:01,189 --> 01:19:59,040

now it turns out that

2177

01:20:04,070 --> 01:20:01,199

these two species ortho and para water

2178

01:20:06,149 --> 01:20:04,080

almost like two independent elements

2179

01:20:09,430 --> 01:20:06,159

there uh might as well be oxygen and

2180

01:20:12,149 --> 01:20:09,440

nitrogen because although uh

2181

01:20:14,149 --> 01:20:12,159

it's a bit of an over uh statement but

2182

01:20:16,870 --> 01:20:14,159

you can actually convert one to the

2183

01:20:19,750 --> 01:20:16,880

other uh not too with not too much

2184

01:20:22,790 --> 01:20:19,760

difficulty but doing it differentially

2185

01:20:25,350 --> 01:20:22,800

is extremely difficult and requires a

2186

01:20:28,149 --> 01:20:25,360

huge number of collisions you need to

2187

01:20:31,030 --> 01:20:28,159

do it in the presence of a non-uniform

2188

01:20:32,870 --> 01:20:31,040

external magnetic field so you need a

2189

01:20:34,149 --> 01:20:32,880

something like a paramagnetic substance

2190

01:20:36,229 --> 01:20:34,159

like platinum

2191

01:20:38,149 --> 01:20:36,239

or another

2192

01:20:39,990 --> 01:20:38,159

molecule that has an unpaired electron

2193

01:20:42,070 --> 01:20:40,000

like molecular oxygen

2194

01:20:44,709 --> 01:20:42,080

and so forth but otherwise

2195

01:20:46,550 --> 01:20:44,719

mere sublimation does not do it

2196

01:20:47,830 --> 01:20:46,560

the simple warming of a substance does

2197

01:20:49,910 --> 01:20:47,840

not do it

2198

01:20:51,750 --> 01:20:49,920

uh and so on the most extreme example is

2199

01:20:54,870 --> 01:20:51,760

molecular hydrogen of course which has

2200

01:20:56,550 --> 01:20:54,880

been studied for since the 20s

2201

01:20:58,630 --> 01:20:56,560

of the last century

2202

01:20:59,750 --> 01:20:58,640

uh in this parameter and it was shown

2203

01:21:02,550 --> 01:20:59,760

that

2204

01:21:05,510 --> 01:21:02,560

the ortho power ratio remains conserved

2205

01:21:07,110 --> 01:21:05,520

for basically the length of the

2206

01:21:08,709 --> 01:21:07,120

lifetime of the universe

2207

01:21:11,030 --> 01:21:08,719

if it's not in the presence of one of

2208

01:21:12,870 --> 01:21:11,040

these paramagnetic substances

2209

01:21:14,310 --> 01:21:12,880

now i don't want to give the impression

2210

01:21:17,510 --> 01:21:14,320

that we understand everything there is

2211

01:21:19,590 --> 01:21:17,520

to know about opr's because in fact the

2212

01:21:22,390 --> 01:21:19,600

exact interpretation of the opr is still

2213

01:21:25,189 --> 01:21:22,400

controversial we don't really know

2214

01:21:28,709 --> 01:21:25,199

based on laboratory measurements

2215

01:21:30,550 --> 01:21:28,719

how long the conversion time is yet we

2216

01:21:32,550 --> 01:21:30,560

do see this and when we look at two

2217

01:21:33,990 --> 01:21:32,560

dissimilar species

2218

01:21:36,470 --> 01:21:34,000

for example

2219

01:21:38,550 --> 01:21:36,480

kawakita

2220

01:21:39,830 --> 01:21:38,560

has looked at the spin temperature in

2221

01:21:42,390 --> 01:21:39,840

ammonia

2222

01:21:44,229 --> 01:21:42,400

and he finds that if you say for water

2223

01:21:47,750 --> 01:21:44,239

he does can do water as well but say you

2224

01:21:48,950 --> 01:21:47,760

do water it has an opr of maybe 2.4

2225

01:21:51,270 --> 01:21:48,960

ammonia

2226

01:21:53,669 --> 01:21:51,280

are of 1.0

2227

01:21:55,990 --> 01:21:53,679

very different but when you can convert

2228

01:21:57,270 --> 01:21:56,000

that to a spin temperature they are the

2229

01:21:58,870 --> 01:21:57,280

same

2230

01:22:01,750 --> 01:21:58,880

so that's telling you that these two

2231

01:22:03,830 --> 01:22:01,760

molecules have experienced the same

2232

01:22:05,910 --> 01:22:03,840

physics the same

2233

01:22:07,030 --> 01:22:05,920

if you like boltzmann physics that has

2234

01:22:09,830 --> 01:22:07,040

set their

2235

01:22:11,830 --> 01:22:09,840

spin ratios at their respective values

2236

01:22:13,110 --> 01:22:11,840

characteristic of that common

2237

01:22:14,790 --> 01:22:13,120

temperature

2238

01:22:17,590 --> 01:22:14,800

and that's a very strong line of

2239

01:22:20,070 --> 01:22:17,600
evidence we're now pursuing uh

2240

01:22:21,990 --> 01:22:20,080
methane uh as are others

2241

01:22:24,629 --> 01:22:22,000
uh we want to do this for ethane as well

2242

01:22:26,870 --> 01:22:24,639
and other hydrocarbons like formaldehyde

2243

01:22:28,070 --> 01:22:26,880
and mike desantis pursuing that for

2244

01:22:30,229 --> 01:22:28,080
example

2245

01:22:32,310 --> 01:22:30,239
and so on so we think this is a very

2246

01:22:34,390 --> 01:22:32,320
important uh

2247

01:22:36,950 --> 01:22:34,400
cosmogonic parameter and we want to

2248

01:22:38,629 --> 01:22:36,960
fully exploit it and as uh has

2249

01:22:40,390 --> 01:22:38,639
instrumentation improves and more time

2250

01:22:43,590 --> 01:22:40,400
is available to telescopes so we are in

2251

01:22:46,470 --> 01:22:45,189

in fact that's very reassuring i think

2252

01:22:48,310 --> 01:22:46,480

the other nice thing about is it

2253

01:22:49,669 --> 01:22:48,320

provides i think the best estimate we

2254

01:22:51,430 --> 01:22:49,679

have for mid plane temperatures in

2255

01:22:52,870 --> 01:22:51,440

regions where the comets form so for

2256

01:22:57,189 --> 01:22:52,880

theorists like me it's great stuff to

2257

01:23:01,910 --> 01:22:59,830

okay one last opportunity to ask mike

2258

01:23:03,430 --> 01:23:01,920

any remaining questions

2259

01:23:05,270 --> 01:23:03,440

and i'm sure you can pursue things with

2260

01:23:07,510 --> 01:23:05,280

him offline

2261

01:23:13,750 --> 01:23:07,520

and if not mike thank you again for a

2262

01:23:18,229 --> 01:23:16,149

thank you as well thank you as well to

2263

01:23:19,990 --> 01:23:18,239

everyone who was uh still hanging in

2264

01:23:22,229 --> 01:23:20,000

there with us 90 minutes after we

2265

01:23:23,830 --> 01:23:22,239

started uh remember that on monday of

2266

01:23:26,149 --> 01:23:23,840

next week we'll be hearing from roger

2267

01:23:28,550 --> 01:23:26,159

summons and on wednesday of next week

2268

01:23:31,030 --> 01:23:28,560

from karen meach for the mit and hawaii