AbGradCon 2018

1
00:00:00,260 --> 00:00:10,870
[Music]

2
00:00:15,740 --> 00:00:13,570
Thanks yeah so maybe another talk

3
00:00:18,109 --> 00:00:15,750
another talk title for this could be

4
00:00:20,630 --> 00:00:18,119
where does interstellar nitrogen

5
00:00:22,340 --> 00:00:20,640
fixation happen so that's really what I

6
00:00:24,140 --> 00:00:22,350
want to think about is where do you

7
00:00:27,200 --> 00:00:24,150
start making interesting nitrogen

8
00:00:28,880 --> 00:00:27,210
bearing compounds in the universe I see

9
00:00:31,580 --> 00:00:28,890
we've already kind of we seen this slide

10
00:00:32,930 --> 00:00:31,590
but I just to go back to it the the

11
00:00:34,790 --> 00:00:32,940
really interesting thing here and the

12
00:00:36,650 --> 00:00:34,800
important thing to remember is that if

13
00:00:38,330 --> 00:00:36,660

you want to think about the initial

14
00:00:39,950 --> 00:00:38,340
conditions for building life on a planet

15
00:00:41,810 --> 00:00:39,960
you really need to think about the

16
00:00:43,639 --> 00:00:41,820
chemistry that happens and all these

17
00:00:45,319 --> 00:00:43,649
phases that lead up to it because each

18
00:00:47,779 --> 00:00:45,329
phase depends on the one before it and

19
00:00:50,270 --> 00:00:47,789
the chemical inventories you find in

20
00:00:52,610 --> 00:00:50,280
things like meteorites and asteroids and

21
00:00:55,069 --> 00:00:52,620
comets as well as just the chemical

22
00:00:57,610 --> 00:00:55,079
abundances the planets start with depend

23
00:00:59,840 --> 00:00:57,620
on the early stages of the chemistry so

24
00:01:01,430 --> 00:00:59,850
there's a bit of a problem I'll talk

25
00:01:03,979 --> 00:01:01,440
about today which is the nitrogen

26
00:01:06,260 --> 00:01:03,989
problem so once you go into the

27
00:01:07,700 --> 00:01:06,270
protoplanetary disk phase of formation

28
00:01:09,980 --> 00:01:07,710
this is after the clouds mostly

29
00:01:12,950 --> 00:01:09,990
dissipated you have a disk of gas and

30
00:01:14,539 --> 00:01:12,960
dust and in the mid plane the larger

31
00:01:16,210 --> 00:01:14,549
pieces of dust start to set them out and

32
00:01:18,710 --> 00:01:16,220
these are the seeds for forming planets

33
00:01:21,080 --> 00:01:18,720
but what happens is you build up a

34
00:01:22,340 --> 00:01:21,090
temperature gradient so close to the

35
00:01:23,929 --> 00:01:22,350
star it's warm and as you move further

36
00:01:24,620 --> 00:01:23,939
and further away it gets colder and

37
00:01:25,940 --> 00:01:24,630
colder

38
00:01:28,580 --> 00:01:25,950

and you hit what are called snow lines

39
00:01:30,499 --> 00:01:28,590
so at some point about 150 Kelvin the

40
00:01:32,420 --> 00:01:30,509
water snow line happens and that water

41
00:01:36,410 --> 00:01:32,430
freezes out and further out you get co2

42
00:01:38,810 --> 00:01:36,420
Co and n2 snow line and so in a really

43
00:01:41,240 --> 00:01:38,820
simplistic view this is the material

44
00:01:43,520 --> 00:01:41,250
that is going to be treated onto your

45
00:01:45,380 --> 00:01:43,530
planet so you switch to a top-down view

46
00:01:47,420 --> 00:01:45,390
if you move further and further out you

47
00:01:48,920 --> 00:01:47,430
get water ice and ammonia and clathrates

48
00:01:51,889 --> 00:01:48,930
and things like that so if you form a

49
00:01:53,899 --> 00:01:51,899
planet fairly close in inside the water

50
00:01:56,510 --> 00:01:53,909
snow mind like an earth what you get is

51
00:01:57,830 --> 00:01:56,520
a silicate rich water poor planet but as

52
00:01:59,870 --> 00:01:57,840
you move further and further out you

53
00:02:03,980 --> 00:01:59,880
make gas and ice giants and these have

54
00:02:06,080 --> 00:02:03,990
very different elemental composition and

55
00:02:08,990 --> 00:02:06,090
so one of the interesting problems you

56
00:02:10,910 --> 00:02:09,000
have is that in two is highly volatile

57
00:02:12,559 --> 00:02:10,920
it doesn't it evaporates at a

58
00:02:15,710 --> 00:02:12,569
very low temperature so if you form

59
00:02:17,660 --> 00:02:15,720
farther in things non-volatile and

60
00:02:21,199 --> 00:02:17,670
nitrogen bearing species are still there

61
00:02:21,890 --> 00:02:21,209
but things like and two are already

62
00:02:24,620 --> 00:02:21,900
blown away

63
00:02:26,449 --> 00:02:24,630

so I one of the big questions is how do

64
00:02:28,670 --> 00:02:26,459
you make or how do you fix nitrogen in

65
00:02:32,090 --> 00:02:28,680
the interstellar interstellar

66
00:02:34,760 --> 00:02:32,100
environment and the basic way you do

67
00:02:36,620 --> 00:02:34,770
this it's through cosmic rays so this is

68
00:02:39,050 --> 00:02:36,630
why interstellar chemistry looks kind of

69
00:02:40,970 --> 00:02:39,060
weird you start with a cosmic ray that's

70
00:02:43,880 --> 00:02:40,980
a really energetic electron or proton

71
00:02:45,650 --> 00:02:43,890
that ionized helium and this is the

72
00:02:48,800 --> 00:02:45,660
important step because n2 is just so

73
00:02:50,690 --> 00:02:48,810
darn hard to crack that you really need

74
00:02:52,250 --> 00:02:50,700
something very energetic to break it

75
00:02:56,870 --> 00:02:52,260
apart you split it into n and n plus

76
00:02:58,190 --> 00:02:56,880
this can make things like an O and H you

77
00:02:59,840 --> 00:02:58,200
know again and then the problem is

78
00:03:01,729 --> 00:02:59,850
sometimes you've cycled back and down to

79
00:03:04,850 --> 00:03:01,739
and you've lost this back to just an

80
00:03:07,789 --> 00:03:04,860
unreactive species if you have ch3 or h

81
00:03:10,400 --> 00:03:07,799
do present you can make hydrogen cyanide

82
00:03:13,640 --> 00:03:10,410
or further on methyl cyanide and this is

83
00:03:15,740 --> 00:03:13,650
the molecule focus on today I so really

84
00:03:17,650 --> 00:03:15,750
figuring out which pathways are active

85
00:03:20,300 --> 00:03:17,660
and how these run determines how you

86
00:03:22,190 --> 00:03:20,310
fraction eight molecules into more

87
00:03:23,780 --> 00:03:22,200
interesting and reactive species you can

88
00:03:25,910 --> 00:03:23,790

use and that are retained during

89
00:03:28,400 --> 00:03:25,920
accretion or more volatile species that

90
00:03:30,530 --> 00:03:28,410
are less helpful I also if you want to

91
00:03:32,449 --> 00:03:30,540
build up bigger complex oxygen bearing

92
00:03:36,110 --> 00:03:32,459
species so through things like

93
00:03:37,699 --> 00:03:36,120
protonated methanol I this works pretty

94
00:03:40,099 --> 00:03:37,709
well when there's not a ton of ammonia

95
00:03:42,710 --> 00:03:40,109
present but as you make ammonia through

96
00:03:45,199 --> 00:03:42,720
pathway similar to this this completely

97
00:03:47,210 --> 00:03:45,209
shuts this route down so not only I

98
00:03:48,979 --> 00:03:47,220
business matter for how you make

99
00:03:50,990 --> 00:03:48,989
nitrogen bearing species it also has

100
00:03:55,099 --> 00:03:51,000
knock-on effects for other complex

101
00:03:56,840 --> 00:03:55,109
chemistry that happens and so the other

102
00:03:58,340 --> 00:03:56,850
process that can happen this by the way

103
00:04:00,080 --> 00:03:58,350
all the stuff I showed is entirely in

104
00:04:01,729 --> 00:04:00,090
the gas phase but these molecules once

105
00:04:04,280 --> 00:04:01,739
you start making these small species

106
00:04:05,960 --> 00:04:04,290
they can accrete on to these very small

107
00:04:07,610 --> 00:04:05,970
dust grains these are the seeds that

108
00:04:09,110 --> 00:04:07,620
will eventually aggregate together to

109
00:04:11,360 --> 00:04:09,120
form planets but for now they're just a

110
00:04:13,789 --> 00:04:11,370
little micron size dust grains and they

111
00:04:15,710 --> 00:04:13,799
create a nice layer of ice so once you

112
00:04:17,390 --> 00:04:15,720
accrete them on to the ice grain they

113
00:04:19,789 --> 00:04:17,400

roam around and find each other and

114
00:04:21,979 --> 00:04:19,799
react but the recombination 2n2 is much

115
00:04:22,670 --> 00:04:21,989
slower so these reactions are actually

116
00:04:25,840 --> 00:04:22,680
much more fish

117
00:04:28,460 --> 00:04:25,850
making things like it's cyanides so this

118
00:04:30,110 --> 00:04:28,470
understanding exactly where if it's in

119
00:04:31,760 --> 00:04:30,120
the gas phase or if it's on grain

120
00:04:33,740 --> 00:04:31,770
surfaces a really big part of

121
00:04:35,480 --> 00:04:33,750
understanding how this chemistry runs

122
00:04:38,180 --> 00:04:35,490
and how you partition your nitrogen out

123
00:04:40,100 --> 00:04:38,190
and so I've been focusing on the

124
00:04:42,409 --> 00:04:40,110
cyanides for a very specific reason and

125
00:04:45,379 --> 00:04:42,419
that's result from something called the

126
00:04:48,050 --> 00:04:45,389
hexo survey so this is just the result

127
00:04:49,909 --> 00:04:48,060
from it so these are all the these are

128
00:04:51,409 --> 00:04:49,919
all the molecules right here the large

129
00:04:53,990 --> 00:04:51,419
majority of the molecules that were

130
00:04:56,960 --> 00:04:54,000
detected and each pie chart is a

131
00:04:58,850 --> 00:04:56,970
molecule and the cuddler tells you what

132
00:05:01,490 --> 00:04:58,860
fraction of that molecule was found in a

133
00:05:03,620 --> 00:05:01,500
warm medium or hot or cold environment

134
00:05:06,070 --> 00:05:03,630
and so the this was a really fantastic

135
00:05:08,390 --> 00:05:06,080
survey because it gave us the most

136
00:05:10,219 --> 00:05:08,400
precise determination of this and

137
00:05:11,810 --> 00:05:10,229
unfortunately it's such a huge beam on

138
00:05:13,339 --> 00:05:11,820

the sky it averages over a ton of

139
00:05:15,350 --> 00:05:13,349
different environments within its source

140
00:05:16,760 --> 00:05:15,360
you can't be really specific you don't

141
00:05:19,219 --> 00:05:16,770
know exactly where it's coming from but

142
00:05:21,620 --> 00:05:19,229
basically what you see is that anything

143
00:05:23,570 --> 00:05:21,630
with a cyanide in it consistently shows

144
00:05:26,360 --> 00:05:23,580
up with having a much warmer component

145
00:05:28,640 --> 00:05:26,370
than anything else and so this green

146
00:05:30,920 --> 00:05:28,650
doubt this is a trend this is a very

147
00:05:32,960 --> 00:05:30,930
obvious simple thing that you can try to

148
00:05:35,180 --> 00:05:32,970
model and understand and actually figure

149
00:05:37,129 --> 00:05:35,190
out what's going on because if you can

150
00:05:38,899 --> 00:05:37,139
if you can't understand such a simple

151
00:05:41,120 --> 00:05:38,909
thing why are cyanides consistently

152
00:05:42,500 --> 00:05:41,130
warmer than everything else you're kind

153
00:05:45,830 --> 00:05:42,510
of a creek for understanding more

154
00:05:48,020 --> 00:05:45,840
complex chemistry so the two ideas we

155
00:05:51,200 --> 00:05:48,030
came up with for how this can happen are

156
00:05:53,089 --> 00:05:51,210
one cyanide chemistry is only efficient

157
00:05:56,659 --> 00:05:53,099
at very warm temperatures so in the gas

158
00:05:58,850 --> 00:05:56,669
phase because if you're on an ice you

159
00:06:00,649 --> 00:05:58,860
don't you know once you hit a hundred

160
00:06:04,040 --> 00:06:00,659
and fifty Kelvin you're not nice anymore

161
00:06:06,770 --> 00:06:04,050
you're in the gas phase so these gas

162
00:06:08,810 --> 00:06:06,780
phase reactions at work at 300 Kelvin

163
00:06:10,640 --> 00:06:08,820

may be very efficient but if you're not

164
00:06:14,839 --> 00:06:10,650
hot enough you just don't make cyanides

165
00:06:16,010 --> 00:06:14,849
the other idea is that it's just that

166
00:06:18,589 --> 00:06:16,020
night trials are very sticky

167
00:06:20,270 --> 00:06:18,599
once you embed them in a nice they don't

168
00:06:22,129 --> 00:06:20,280
evaporate until much warmer temperature

169
00:06:24,560 --> 00:06:22,139
so radio telescopes like the one that

170
00:06:26,240 --> 00:06:24,570
did this work are completely blind to

171
00:06:27,589 --> 00:06:26,250
anything that's not in the gas phase so

172
00:06:29,570 --> 00:06:27,599
it's not in the gas phase you don't know

173
00:06:31,190 --> 00:06:29,580
about it and so maybe you just have to

174
00:06:33,110 --> 00:06:31,200
heat these grains up to much higher

175
00:06:34,640 --> 00:06:33,120
temperatures to actually get this in the

176
00:06:36,530 --> 00:06:34,650
gas phase where the panel scope can see

177
00:06:38,240 --> 00:06:36,540
it so the question is

178
00:06:41,000 --> 00:06:38,250
which one of those two things happen

179
00:06:42,350 --> 00:06:41,010
because it has a very big effect on how

180
00:06:43,520 --> 00:06:42,360
you would model the chemistry and how

181
00:06:46,220 --> 00:06:43,530
you think about it

182
00:06:48,200 --> 00:06:46,230
and so the best idea we've come up with

183
00:06:49,640 --> 00:06:48,210
through the how to figure out how to

184
00:06:51,380 --> 00:06:49,650
differentiate between these two because

185
00:06:53,870 --> 00:06:51,390
our observations don't really tell us

186
00:06:55,610 --> 00:06:53,880
which one is which is to use something

187
00:06:58,280 --> 00:06:55,620
called the kinetic isotope effects and

188
00:06:59,540 --> 00:06:58,290

again this was brought up last night and

189
00:07:01,580 --> 00:06:59,550
actually explained very well so I won't

190
00:07:04,340 --> 00:07:01,590
belabor the point but just say that I

191
00:07:07,190 --> 00:07:04,350
when you substitute a deuterium for a

192
00:07:09,560 --> 00:07:07,200
hydrogen its thermodynamically favored

193
00:07:11,270 --> 00:07:09,570
so exponentially so so at 10 Kelvin or

194
00:07:14,270 --> 00:07:11,280
20 Kelvin where a lot of these reactions

195
00:07:16,970 --> 00:07:14,280
happen this is a huge effect and this is

196
00:07:18,800 --> 00:07:16,980
best demonstrated by nd 3 so the

197
00:07:21,980 --> 00:07:18,810
interstellar abundance of deuterium is

198
00:07:23,810 --> 00:07:21,990
10 to the minus 5 so statistically if

199
00:07:25,340 --> 00:07:23,820
you wanted to find this or if you wanted

200
00:07:27,560 --> 00:07:25,350
to guess how abundant this is this would

201
00:07:30,230 --> 00:07:27,570
be 15 orders of magnitude lesson

202
00:07:31,970 --> 00:07:30,240
abundant than ammonia that's not the

203
00:07:34,370 --> 00:07:31,980
case it's enhanced by a factor of about

204
00:07:36,980 --> 00:07:34,380
10 million over the statistical

205
00:07:39,200 --> 00:07:36,990
abundance so it's a sign that really

206
00:07:41,240 --> 00:07:39,210
cold chemistry pushes deuterium into

207
00:07:43,220 --> 00:07:41,250
these bonds very efficiently and you can

208
00:07:45,440 --> 00:07:43,230
use this to measure what the temperature

209
00:07:47,750 --> 00:07:45,450
was when the bond was formed not what it

210
00:07:49,940 --> 00:07:47,760
is now but what it was when it was

211
00:07:51,140 --> 00:07:49,950
formed and this is one of the great and

212
00:07:53,330 --> 00:07:51,150
really terrible things about

213
00:07:55,460 --> 00:07:53,340

astrochemistry is that it is not

214
00:07:57,850 --> 00:07:55,470
thermodynamic so you're not at a

215
00:08:01,100 --> 00:07:57,860
thermodynamic equilibrium ever so

216
00:08:02,630 --> 00:08:01,110
history matters so it's a really nice

217
00:08:04,490 --> 00:08:02,640
thing because you can figure out what

218
00:08:07,040 --> 00:08:04,500
happened if you're looking at something

219
00:08:08,810 --> 00:08:07,050
today you can imply err infer what

220
00:08:10,700 --> 00:08:08,820
happened you know hundreds of thousands

221
00:08:12,830 --> 00:08:10,710
of years ago but downside is you want to

222
00:08:14,210 --> 00:08:12,840
understand this you have to model what

223
00:08:18,320 --> 00:08:14,220
happened hundreds of thousands of years

224
00:08:20,990 --> 00:08:18,330
ago so but the idea here is that if you

225
00:08:23,150 --> 00:08:21,000
can measure the deuterium fraction and

226
00:08:24,800 --> 00:08:23,160
the temperature at the same time you can

227
00:08:28,040 --> 00:08:24,810
break the degeneracy and actually work

228
00:08:30,110 --> 00:08:28,050
out how nitriles and other molecules are

229
00:08:32,780 --> 00:08:30,120
formed and what environment they're

230
00:08:35,180 --> 00:08:32,790
formed in so to do this we went to be

231
00:08:37,430 --> 00:08:35,190
Alma Observatory that's the Atacama

232
00:08:40,490 --> 00:08:37,440
Large millimeter array it's an array of

233
00:08:42,110 --> 00:08:40,500
44 12-metre antennas in the Atacama

234
00:08:44,390 --> 00:08:42,120
Desert in northern Chile it is

235
00:08:45,740 --> 00:08:44,400
absolutely fantastic it's just come

236
00:08:47,420 --> 00:08:45,750
online in the last couple years and

237
00:08:50,170 --> 00:08:47,430
completely change the way we do radio

238
00:08:52,570 --> 00:08:50,180

astronomy I so the idea here

239
00:08:54,730 --> 00:08:52,580
to go through one of these two scenarios

240
00:08:56,290 --> 00:08:54,740
basically if you have great surface

241
00:08:59,980 --> 00:08:56,300
formation this happens at very low

242
00:09:01,870 --> 00:08:59,990
temperatures so the the the deuterium or

243
00:09:03,220 --> 00:09:01,880
the CV bond is made at a very low

244
00:09:07,090 --> 00:09:03,230
temperature and then eventually

245
00:09:09,519 --> 00:09:07,100
evaporated so if you find methyl cyanide

246
00:09:10,960 --> 00:09:09,529
in a slightly warmer environment or if

247
00:09:12,910 --> 00:09:10,970
you see a gradient in temperature but

248
00:09:14,650 --> 00:09:12,920
the deuterium fraction is constant that

249
00:09:16,510 --> 00:09:14,660
tells you that it was made cold and now

250
00:09:19,150 --> 00:09:16,520
you've just heated it up if the

251
00:09:21,010 --> 00:09:19,160
deuterium fraction changes with the

252
00:09:22,780 --> 00:09:21,020
excitation temperature or the local

253
00:09:25,510 --> 00:09:22,790
temperature it tells you that that bond

254
00:09:26,920 --> 00:09:25,520
is being made right there right then and

255
00:09:30,310 --> 00:09:26,930
that's a sign that it's gas phase

256
00:09:32,740 --> 00:09:30,320
chemistry but that's exactly what we did

257
00:09:35,019 --> 00:09:32,750
we asked for time in cycle three and we

258
00:09:38,829 --> 00:09:35,029
rewarded actually we did all this and

259
00:09:41,050 --> 00:09:38,839
only half an hour but we were very lucky

260
00:09:42,670 --> 00:09:41,060
because we had to do this in a very

261
00:09:44,290 --> 00:09:42,680
extended configuration so the beauty of

262
00:09:45,880 --> 00:09:44,300
this telescope is you can pick up

263
00:09:47,620 --> 00:09:45,890

individual antennas and move them around

264
00:09:50,470 --> 00:09:47,630
and change the resolution of the

265
00:09:52,000 --> 00:09:50,480
telescope by doing interferometry you

266
00:09:54,370 --> 00:09:52,010
can actually piece back together the

267
00:09:56,140 --> 00:09:54,380
entire image of your source an

268
00:09:57,970 --> 00:09:56,150
incredibly high spatial resolution so

269
00:10:00,250 --> 00:09:57,980
the trick here is that you actually need

270
00:10:02,470 --> 00:10:00,260
to be able to see the source with enough

271
00:10:04,090 --> 00:10:02,480
resolution to spot the temperature

272
00:10:06,660 --> 00:10:04,100
gradient happening if you just average

273
00:10:08,920 --> 00:10:06,670
over a whole big complex thing you don't

274
00:10:10,750 --> 00:10:08,930
there's no good way to figure out what

275
00:10:11,949 --> 00:10:10,760
happens you just sort of summing up a

276
00:10:15,640 --> 00:10:11,959
bunch of things that you're not really

277
00:10:17,650 --> 00:10:15,650
sure what they are and so the the

278
00:10:18,970 --> 00:10:17,660
original work showing the cyanides were

279
00:10:21,190 --> 00:10:18,980
much warmer with done in a couple

280
00:10:24,400 --> 00:10:21,200
sources one of them is Orion so you're

281
00:10:26,680 --> 00:10:24,410
familiar with the constellation right

282
00:10:29,079 --> 00:10:26,690
here is the nebula we take a zoom in

283
00:10:31,510 --> 00:10:29,089
this is the trapezium and then up here

284
00:10:33,490 --> 00:10:31,520
is the actual nebula surrounded by this

285
00:10:35,140 --> 00:10:33,500
this is maybe the least pretty picture

286
00:10:37,180 --> 00:10:35,150
of Orion you can find if you google

287
00:10:38,530 --> 00:10:37,190
they're much nicer ones but they don't

288
00:10:43,030 --> 00:10:38,540

really show you what's happening so

289
00:10:45,640 --> 00:10:43,040
we're looking right here at the yeah so

290
00:10:48,430 --> 00:10:45,650
if you zoom in one more time yet these

291
00:10:49,900 --> 00:10:48,440
are explosive outflows caused by an

292
00:10:51,880 --> 00:10:49,910
interaction about five hundred years ago

293
00:10:54,250 --> 00:10:51,890
so that sets the dynamical time for the

294
00:10:55,900 --> 00:10:54,260
whole thing and then the nebula we're

295
00:10:57,460 --> 00:10:55,910
looking at it's right in here the the

296
00:10:59,500 --> 00:10:57,470
black spot isn't a lack of something

297
00:11:02,199 --> 00:10:59,510
it's foreground us the actual nebula we

298
00:11:03,550 --> 00:11:02,209
want to look at so this is the optical

299
00:11:06,130 --> 00:11:03,560
image and now switch

300
00:11:07,450 --> 00:11:06,140
the radio and so now it completely

301
00:11:09,790 --> 00:11:07,460
changes where the at where there was

302
00:11:11,950 --> 00:11:09,800
nothing this is a continuum image of the

303
00:11:14,530 --> 00:11:11,960
warm dust and it turns out Orion is

304
00:11:16,269 --> 00:11:14,540
incredibly spatially complex source each

305
00:11:19,900 --> 00:11:16,279
one of these is a point source these are

306
00:11:21,700 --> 00:11:19,910
probably protostars or other clumps of

307
00:11:24,550 --> 00:11:21,710
gas and dust that are either already

308
00:11:26,890 --> 00:11:24,560
fusing or are condensing down and will

309
00:11:30,280 --> 00:11:26,900
start becoming actual stars and planets

310
00:11:31,720 --> 00:11:30,290
and the link scale here that's a 137 au

311
00:11:34,990 --> 00:11:31,730
that's about the outer edge of the solar

312
00:11:37,480 --> 00:11:35,000
system so each each one of these is a

313
00:11:39,910 --> 00:11:37,490

whole solar system across but the nice

314
00:11:42,490 --> 00:11:39,920
thing is our pixel size is about the

315
00:11:43,750 --> 00:11:42,500
orbit of Neptune so we can see as

316
00:11:45,670 --> 00:11:43,760
something's heating up we can actually

317
00:11:48,400 --> 00:11:45,680
see the temperature gradients happening

318
00:11:50,290 --> 00:11:48,410
and so the really nice thing about Alma

319
00:11:52,269 --> 00:11:50,300
is it's not just an image it's a data

320
00:11:54,400 --> 00:11:52,279
cube so at each pixel we get a spectrum

321
00:11:55,660 --> 00:11:54,410
and the spectrum looked like this so

322
00:11:58,390 --> 00:11:55,670
it's a huge amount of data that comes

323
00:12:01,660 --> 00:11:58,400
through this is just one of our spectra

324
00:12:03,480 --> 00:12:01,670
of deuterated methyl cyanide so the each

325
00:12:05,560 --> 00:12:03,490
one of these is aligned the relative

326
00:12:07,210 --> 00:12:05,570
abundance between these tells you the

327
00:12:09,970 --> 00:12:07,220
temperature the absolute abundance tells

328
00:12:11,590 --> 00:12:09,980
you about the abundance and so we

329
00:12:13,810 --> 00:12:11,600
measured this and then a couple of

330
00:12:16,630 --> 00:12:13,820
carbon-13 methyl cyanide lines we can't

331
00:12:18,940 --> 00:12:16,640
actually measure the non carbon-13 lines

332
00:12:20,740 --> 00:12:18,950
so easily but we measure these together

333
00:12:22,750 --> 00:12:20,750
so we go through as we fit the

334
00:12:25,150 --> 00:12:22,760
temperature and the abundance of

335
00:12:26,829 --> 00:12:25,160
deuterated cyanide and carbon 13 cyanide

336
00:12:28,810 --> 00:12:26,839
at the same time at every single pixel

337
00:12:31,470 --> 00:12:28,820
throughout the cube that gives us our

338
00:12:33,880 --> 00:12:31,480

deuterium fraction in our temperature

339
00:12:36,430 --> 00:12:33,890
I'm just to show you we can actually do

340
00:12:37,990 --> 00:12:36,440
this so we have here this is the

341
00:12:40,000 --> 00:12:38,000
temperature we fit each one of these

342
00:12:41,530 --> 00:12:40,010
sources so we find about six unique

343
00:12:43,360 --> 00:12:41,540
sources wearing actually detect stuff

344
00:12:44,560 --> 00:12:43,370
it's not that there's nothing no data

345
00:12:46,180 --> 00:12:44,570
and these other points but these are the

346
00:12:48,699 --> 00:12:46,190
only places where we find sufficient

347
00:12:50,290 --> 00:12:48,709
abundance to actually do the bits and we

348
00:12:52,270 --> 00:12:50,300
can actually resolve like in up around

349
00:12:54,490 --> 00:12:52,280
the hot core here so this is an active

350
00:12:57,010 --> 00:12:54,500
and outflowing protostar and in front of

351
00:12:58,480 --> 00:12:57,020
it we see really hot gas that tapers off

352
00:13:00,910 --> 00:12:58,490
into cooler gas we can actually measure

353
00:13:02,680 --> 00:13:00,920
this on a scale that's you know

354
00:13:04,240 --> 00:13:02,690
commensurate with how with the actual

355
00:13:06,490 --> 00:13:04,250
heating mechanism so you actually get in

356
00:13:08,500 --> 00:13:06,500
there and see you know these things in

357
00:13:11,860 --> 00:13:08,510
detail sufficient enough to measure this

358
00:13:14,170 --> 00:13:11,870
now if we fit the D to H ratio the log D

359
00:13:15,520 --> 00:13:14,180
to H ratio we plot it so if down here 10

360
00:13:17,200 --> 00:13:15,530
to the minus 5 that's what you would

361
00:13:19,300 --> 00:13:17,210
expect if you just took the interstellar

362
00:13:21,430 --> 00:13:19,310
which each one of the colors is just a

363
00:13:23,830 --> 00:13:21,440

different clump we measure they're all

364
00:13:25,800 --> 00:13:23,840
incredibly enriched in deuterium so much

365
00:13:28,900 --> 00:13:25,810
so that these all had to form at

366
00:13:30,790 --> 00:13:28,910
something like 10 or 20 Kelvin so this

367
00:13:32,830 --> 00:13:30,800
says that this is entirely grain surface

368
00:13:34,510 --> 00:13:32,840
formation that the bulk of this was

369
00:13:36,970 --> 00:13:34,520
formed incredibly cold not in the warm

370
00:13:39,100 --> 00:13:36,980
gas but on a cold grain surface and that

371
00:13:41,350 --> 00:13:39,110
really what you're seeing it's just the

372
00:13:43,210 --> 00:13:41,360
effect of having to heat cyanides

373
00:13:45,450 --> 00:13:43,220
considerably more if you get them off

374
00:13:48,100 --> 00:13:45,460
the grain surface and into the gas

375
00:13:49,990 --> 00:13:48,110
that's the general and interesting thing

376
00:13:52,150 --> 00:13:50,000
the caveat is that if you zoom in on

377
00:13:56,500 --> 00:13:52,160
this and that this structure is all real

378
00:13:58,090 --> 00:13:56,510
I there is signs basically that as you

379
00:14:00,310 --> 00:13:58,100
go up in temperature the deuterium

380
00:14:02,230 --> 00:14:00,320
fraction starts to drop off one each

381
00:14:03,400 --> 00:14:02,240
clump is different so they all show

382
00:14:05,200 --> 00:14:03,410
different behavior a couple of the

383
00:14:08,020 --> 00:14:05,210
really cold clumps actually show

384
00:14:09,490 --> 00:14:08,030
enhanced deuterium as you warm up which

385
00:14:10,870 --> 00:14:09,500
is a little counterintuitive but a lot

386
00:14:12,970 --> 00:14:10,880
of the warmer clumps that we know are

387
00:14:15,010 --> 00:14:12,980
being irradiated are starting to show

388
00:14:17,770 --> 00:14:15,020

drops in deuterium fraction as you heat

389
00:14:19,090 --> 00:14:17,780
them up which would imply that after

390
00:14:21,210 --> 00:14:19,100
you've made this on the grain surface

391
00:14:24,160 --> 00:14:21,220
you start chewing up this prop

392
00:14:28,060 --> 00:14:24,170
population and making a second

393
00:14:31,150 --> 00:14:28,070
population of warmer deuterium or methyl

394
00:14:32,920 --> 00:14:31,160
cyanide so it's not so simple maybe okay

395
00:14:34,630 --> 00:14:32,930
probably what's happening is you make

396
00:14:38,340 --> 00:14:34,640
this stuff cold and then slowly you chew

397
00:14:40,480 --> 00:14:38,350
on it and make a second set so that they

398
00:14:41,710 --> 00:14:40,490
unfortunately not one or the other but

399
00:14:46,480 --> 00:14:41,720
probably a little bit of both that's

400
00:14:47,740 --> 00:14:46,490
happening yeah so with that I just like

401
00:14:49,180 --> 00:14:47,750
to take a second to thank all the

402
00:14:50,050 --> 00:14:49,190
collaborators and people that helped to

403
00:14:51,820 --> 00:14:50,060
make this possible

404
00:15:01,900 --> 00:14:51,830
I thank you all for listening don't

405
00:15:08,770 --> 00:15:01,910
leave my conclusions out questions for

406
00:15:14,870 --> 00:15:13,250
so I'm just wondering because I really

407
00:15:17,240 --> 00:15:14,880
think this mostly preacher that the

408
00:15:19,730 --> 00:15:17,250
methyl has to be created in the cold

409
00:15:21,350 --> 00:15:19,740
environment why do you think that it has

410
00:15:22,700 --> 00:15:21,360
to find to the cyanide and the cold

411
00:15:26,750 --> 00:15:22,710
environment because it's deuterium is

412
00:15:28,760 --> 00:15:26,760
coming from just one group so I don't

413
00:15:30,860 --> 00:15:28,770

have complete data from the other

414
00:15:34,220 --> 00:15:30,870
carbon-13 just because it's in a

415
00:15:37,580 --> 00:15:34,230
different band but both the carbon-13

416
00:15:39,050 --> 00:15:37,590
show roughly the same abundance so it

417
00:15:40,580 --> 00:15:39,060
would imply that they're all basically

418
00:15:42,290 --> 00:15:40,590
coming from the same place but the

419
00:15:43,940 --> 00:15:42,300
problem is deuterium fraction or

420
00:15:46,790 --> 00:15:43,950
fractionation depends on mass and

421
00:15:49,030 --> 00:15:46,800
carbon-13 fractionation is so much

422
00:15:50,840 --> 00:15:49,040
weaker and really difficult to prove

423
00:15:53,180 --> 00:15:50,850
especially with our thing with the noise

424
00:15:54,590 --> 00:15:53,190
yeah I would just be interesting to see

425
00:15:56,240 --> 00:15:54,600
if you could get the clothes for the

426
00:15:58,520 --> 00:15:56,250
carbon 13 because that might learn

427
00:16:00,470 --> 00:15:58,530
further prove impossible yeah oh you

428
00:16:03,140 --> 00:16:00,480
talking about the double substitution oh

429
00:16:05,660 --> 00:16:03,150
no no no we need a lot more signal than

430
00:16:07,250 --> 00:16:05,670
noise to do that you know we're working

431
00:16:09,110 --> 00:16:07,260
on it and we've also got another

432
00:16:11,750 --> 00:16:09,120
proposal in to do methanol the same way

433
00:16:15,830 --> 00:16:11,760
but do just the two different the O H

434
00:16:17,450 --> 00:16:15,840
versus the CH 3 hydrogen's yeah so

435
00:16:19,990 --> 00:16:17,460
hopefully that'll that'll get through

436
00:16:22,160 --> 00:16:20,000
sometime soon and I think that also gets

437
00:16:24,560 --> 00:16:22,170
sort of that gets closer to answering

438
00:16:28,430 --> 00:16:24,570

the question because if the if those two

439
00:16:31,580 --> 00:16:28,440
deuterium populations are different yeah

440
00:16:37,150 --> 00:16:31,590
we can barely see 15 mm no we're trying

441
00:16:37,160 --> 00:16:42,610
any other questions