2017 Astrobiology Graduate Conference

Charlottesville, VA

1
00:00:13,879 --> 00:00:10,669
I am Brandon I'm going to be the session

2
00:00:16,430 --> 00:00:13,889
chair for TA molecules he'll might need

3
00:00:18,410 --> 00:00:16,440
how might we blow them up and so your

4
00:00:19,760 --> 00:00:18,420
molecule was blown up how to put cap the

5
00:00:21,710 --> 00:00:19,770
pieces and put Humpty Dumpty back

6
00:00:23,840 --> 00:00:21,720
together again so these are the two

7
00:00:25,370 --> 00:00:23,850
sides of astrochemistry we blow stuff up

8
00:00:27,410 --> 00:00:25,380
and then we put it back together and

9
00:00:31,040 --> 00:00:27,420
I'll give you a little introduction into

10
00:00:34,040 --> 00:00:31,050
how we do all that so first this is our

11
00:00:36,260 --> 00:00:34,050
lab so we start astrochemistry starts

12
00:00:38,060 --> 00:00:36,270
when a star explodes this is a hard

13
00:00:40,310 --> 00:00:38,070

reset to the chemistry you kind of blow

14
00:00:42,740 --> 00:00:40,320
everything up you atomized it and you

15
00:00:45,020 --> 00:00:42,750
start from scratch eventually things

16
00:00:48,139 --> 00:00:45,030
condense back into a cloud of gas and

17
00:00:50,950 --> 00:00:48,149
dust these are usually sort of a few to

18
00:00:53,420 --> 00:00:50,960
hundreds of light-years across very big

19
00:00:54,979 --> 00:00:53,430
eventually we heard a lot about this

20
00:00:57,290 --> 00:00:54,989
yesterday but they start condensing down

21
00:00:58,849 --> 00:00:57,300
into smaller and smaller cores for the

22
00:01:00,860 --> 00:00:58,859
high mass star forming regions you get

23
00:01:02,959 --> 00:01:00,870
many of these like hundreds of these in

24
00:01:05,719 --> 00:01:02,969
a single cloud will condense down into

25
00:01:07,730 --> 00:01:05,729
protostars with disks around them then

26
00:01:10,520 --> 00:01:07,740
they condense even further they form

27
00:01:12,050 --> 00:01:10,530
little planets and planetesimals the big

28
00:01:14,450 --> 00:01:12,060
ones govern but the little ones they

29
00:01:18,109 --> 00:01:14,460
create all of the matter that was left

30
00:01:20,359 --> 00:01:18,119
over and if you're lucky for some places

31
00:01:21,469 --> 00:01:20,369
you get life and for an astrobiology

32
00:01:24,590 --> 00:01:21,479
conference this is what we're really

33
00:01:26,630 --> 00:01:24,600
interested in is which ones of these

34
00:01:28,490 --> 00:01:26,640
systems actually end up with life and

35
00:01:29,600 --> 00:01:28,500
what can astrochemistry add to that

36
00:01:32,630 --> 00:01:29,610
picture

37
00:01:34,880 --> 00:01:32,640
and so astrochemistry isn't really about

38
00:01:37,550 --> 00:01:34,890

any one of these places it's not about

39
00:01:39,200 --> 00:01:37,560
you know supernovae or gas clouds it's

40
00:01:41,780 --> 00:01:39,210
about the process that happens through

41
00:01:43,280 --> 00:01:41,790
this because once you blow this up you

42
00:01:45,469 --> 00:01:43,290
have to start from scratch building

43
00:01:48,170 --> 00:01:45,479
bigger and more complex molecules all

44
00:01:51,649 --> 00:01:48,180
the way through and that's what we study

45
00:01:54,350 --> 00:01:51,659
is how you get from there to about here

46
00:01:55,910 --> 00:01:54,360
once we get to here Astro chemistry's

47
00:02:01,010 --> 00:01:55,920
out this is planetary science or

48
00:02:02,209 --> 00:02:01,020
biology's problem and yeah and so for

49
00:02:04,069 --> 00:02:02,219
the most part today we're going to hear

50
00:02:05,899 --> 00:02:04,079
talks at focus sort of on this area

51
00:02:09,050 --> 00:02:05,909
mostly because these are the most easily

52
00:02:12,199 --> 00:02:09,060
observable eye places where chemistry

53
00:02:13,860 --> 00:02:12,209
happens in the universe and so one of

54
00:02:16,470 --> 00:02:13,870
the really cool things I think

55
00:02:19,710 --> 00:02:16,480
for astrochemistry and what it can tell

56
00:02:21,660 --> 00:02:19,720
you about astrobiology is this if you

57
00:02:25,229 --> 00:02:21,670
look at things like the Murchison

58
00:02:27,240 --> 00:02:25,239
meteorite or comets you see this really

59
00:02:29,250 --> 00:02:27,250
awesome mix of stuff

60
00:02:32,520 --> 00:02:29,260
things like long-chain fatty acids

61
00:02:35,970 --> 00:02:32,530
purines pyrimidines amino acids even

62
00:02:37,470 --> 00:02:35,980
some light sugars that are all just you

63
00:02:39,089 --> 00:02:37,480

just grind this up and extract it and

64
00:02:42,119 --> 00:02:39,099
it's there and this is a meteorite that

65
00:02:44,339 --> 00:02:42,129
fell to earth and you know successfully

66
00:02:46,319 --> 00:02:44,349
delivered this without destroying all of

67
00:02:48,210 --> 00:02:46,329
it and this is kind of a small-scale

68
00:02:50,460 --> 00:02:48,220
example we know comets can do this too

69
00:02:52,710 --> 00:02:50,470
and we know we kind of heard a little

70
00:02:54,960 --> 00:02:52,720
bit about this yesterday that the earth

71
00:02:57,000 --> 00:02:54,970
accreted a pretty sizable amount of

72
00:02:59,430 --> 00:02:57,010
water and other organics as it was

73
00:03:01,140 --> 00:02:59,440
forming through stuff like this the

74
00:03:02,819 --> 00:03:01,150
really cool thing is this is a pristine

75
00:03:04,890 --> 00:03:02,829
record of the solar system at its

76
00:03:06,900 --> 00:03:04,900
earliest point this is chemistry that

77
00:03:09,300 --> 00:03:06,910
this is molecules that were around

78
00:03:11,309 --> 00:03:09,310
before the earth even formed and so the

79
00:03:12,780 --> 00:03:11,319
question is from an astro chemical

80
00:03:15,410 --> 00:03:12,790
perspective how did you make that how do

81
00:03:17,789 --> 00:03:15,420
you get that there how typical is it

82
00:03:19,170 --> 00:03:17,799
what are the inventories you think

83
00:03:21,569 --> 00:03:19,180
you're going to be working with on a

84
00:03:23,849 --> 00:03:21,579
planet that's forming and you know what

85
00:03:26,849 --> 00:03:23,859
can that do for forming life and how

86
00:03:28,620 --> 00:03:26,859
does that happen it's not aliens it's

87
00:03:30,210 --> 00:03:28,630
chemistry it's the same chemistry you

88
00:03:33,930 --> 00:03:30,220

learned about in Gen chem class it's

89
00:03:36,089 --> 00:03:33,940
just applied to a really weird system so

90
00:03:39,990 --> 00:03:36,099
to start with this is our periodic table

91
00:03:42,210 --> 00:03:40,000
so this everything is scaled by size to

92
00:03:43,890 --> 00:03:42,220
the abundance of a molecule in space so

93
00:03:45,300 --> 00:03:43,900
hydrogen is far and away the most

94
00:03:47,909 --> 00:03:45,310
abundant thing you have to work with

95
00:03:49,620 --> 00:03:47,919
next is helium and oxygen carbon

96
00:03:53,970 --> 00:03:49,630
nitrogen all the interesting stuff is

97
00:03:56,250 --> 00:03:53,980
like 1% by number so almost everything

98
00:03:58,710 --> 00:03:56,260
you're dealing with is hydrogen helium

99
00:04:01,740 --> 00:03:58,720
and for stuff we'll hear about later the

100
00:04:03,599 --> 00:04:01,750
dust and ice that is you know one of the

101
00:04:05,250 --> 00:04:03,609
big powerhouses of making more complex

102
00:04:09,180 --> 00:04:05,260
molecules is only about a percent of the

103
00:04:11,069 --> 00:04:09,190
total mass for the beaker

104
00:04:12,690 --> 00:04:11,079
these are usually massive star forming

105
00:04:14,309 --> 00:04:12,700
regions once the clouds of gas and dust

106
00:04:15,930 --> 00:04:14,319
condense that that's where you can

107
00:04:18,449 --> 00:04:15,940
actually start to form molecules these

108
00:04:20,370 --> 00:04:18,459
have masses of you know tens of

109
00:04:24,120 --> 00:04:20,380
thousands to millions of solar masses

110
00:04:25,980 --> 00:04:24,130
these are huge associations once you get

111
00:04:27,540 --> 00:04:25,990
down to the protoplanetary disks they're

112
00:04:28,740 --> 00:04:27,550
pretty tiny but for the

113
00:04:30,059 --> 00:04:28,750

Eggar clouds there hundreds of

114
00:04:32,640 --> 00:04:30,069
light-years across these are enormous

115
00:04:35,369 --> 00:04:32,650
things the densities can start off at

116
00:04:37,760 --> 00:04:35,379
100 molecules per cubic centimeter and

117
00:04:40,350 --> 00:04:37,770
they get higher and higher for reference

118
00:04:42,570 --> 00:04:40,360
the air you're breathing is like 10 to

119
00:04:45,180 --> 00:04:42,580
the 19 molecules per cubic centimeter so

120
00:04:47,219 --> 00:04:45,190
in space especially in the diffuser is

121
00:04:49,469 --> 00:04:47,229
molecules can go months between

122
00:04:51,809 --> 00:04:49,479
colliding with other molecules they are

123
00:04:53,430 --> 00:04:51,819
very lonely they just ping around and

124
00:04:55,050 --> 00:04:53,440
eventually bump into something the

125
00:04:57,719 --> 00:04:55,060
temperatures can get up to a thousand

126
00:04:59,580 --> 00:04:57,729
Kelvin for most places it will start

127
00:05:01,200 --> 00:04:59,590
down at 10 Kelvin as things condense and

128
00:05:03,890 --> 00:05:01,210
eventually warm up to 300 which is

129
00:05:06,749 --> 00:05:03,900
toasty warm for the interstellar medium

130
00:05:09,270 --> 00:05:06,759
and the chemistry looks kind of weird I

131
00:05:11,100 --> 00:05:09,280
mean everybody's taking gen chem so if

132
00:05:13,140 --> 00:05:11,110
you had some equilibrium with these

133
00:05:15,659 --> 00:05:13,150
molecules you'd expect it to end up on

134
00:05:17,369 --> 00:05:15,669
the right here but you have to get

135
00:05:20,999 --> 00:05:17,379
through some intermediate and in space

136
00:05:22,740 --> 00:05:21,009
that's not always so easy so you you

137
00:05:25,140 --> 00:05:22,750
can't describe things by simple

138
00:05:28,350 --> 00:05:25,150

Boltzmann statistics there's barriers in

139
00:05:30,659 --> 00:05:28,360
the way and so the good news is the

140
00:05:32,189 --> 00:05:30,669
history matters so the state of your

141
00:05:35,640 --> 00:05:32,199
system when you see it get a cloud of

142
00:05:37,290 --> 00:05:35,650
gas and dust it depends on the detailed

143
00:05:39,839 --> 00:05:37,300
history of what happened before it so

144
00:05:40,980 --> 00:05:39,849
you can sort of measure you can actually

145
00:05:42,689 --> 00:05:40,990
use this to tell you something about

146
00:05:45,420 --> 00:05:42,699
what happened the bad news is is that

147
00:05:47,430 --> 00:05:45,430
history matters because the details of

148
00:05:49,170 --> 00:05:47,440
you know what's the difference in energy

149
00:05:51,300 --> 00:05:49,180
what's the barrier what are the rates

150
00:05:53,040 --> 00:05:51,310
for all of these things are incredibly

151
00:05:54,180 --> 00:05:53,050
important and if you want to figure out

152
00:05:56,490 --> 00:05:54,190
what the hell's going on you have to

153
00:05:58,110 --> 00:05:56,500
know all of the details that went into

154
00:05:59,519 --> 00:05:58,120
making this to figure it out and that's

155
00:06:03,029 --> 00:05:59,529
millions and millions of parameters

156
00:06:05,430 --> 00:06:03,039
you'd have to know so it turns out to be

157
00:06:06,390 --> 00:06:05,440
really tough and that's a lot of what

158
00:06:07,860 --> 00:06:06,400
we're going to hear about today is

159
00:06:09,629 --> 00:06:07,870
actually figuring out the details of

160
00:06:11,399 --> 00:06:09,639
this so we can actually understand

161
00:06:14,010 --> 00:06:11,409
something about the chemistry that we

162
00:06:15,809 --> 00:06:14,020
see happening in space because it aronia

163
00:06:16,890 --> 00:06:15,819

cleef or something for a field where you

164
00:06:20,459 --> 00:06:16,900
study things that are absolutely

165
00:06:22,110 --> 00:06:20,469
enormous most of the most of the stuff

166
00:06:25,769 --> 00:06:22,120
that comes down to the details knowing

167
00:06:27,930 --> 00:06:25,779
these tiny atomistic details so the two

168
00:06:32,249 --> 00:06:27,940
flavors of chemistry we really work on

169
00:06:34,469 --> 00:06:32,259
studying our gas phase chemistry so in

170
00:06:37,560 --> 00:06:34,479
these big clouds of gas and dust you get

171
00:06:41,100 --> 00:06:37,570
weird chemistry it's driven by ions like

172
00:06:41,790 --> 00:06:41,110
h 3 plus and CH 3 plus and you just

173
00:06:43,050 --> 00:06:41,800
chain things

174
00:06:45,300 --> 00:06:43,060
together in simple bump-bump-bump

175
00:06:47,040 --> 00:06:45,310
reactions but if you want to understand

176
00:06:49,800 --> 00:06:47,050
this you actually need to know something

177
00:06:51,390 --> 00:06:49,810
about all of the rates for everything on

178
00:06:55,589 --> 00:06:51,400
this page and this is one of the simpler

179
00:06:58,170 --> 00:06:55,599
reaction schemes you can think of the

180
00:06:59,969 --> 00:06:58,180
other one will hear a lot about is grain

181
00:07:01,980 --> 00:06:59,979
surface chemistry or ice chemistry so

182
00:07:04,080 --> 00:07:01,990
once things cool down everything

183
00:07:08,010 --> 00:07:04,090
condenses out into these fluffy grains

184
00:07:10,499 --> 00:07:08,020
of usually silicon and carbon and so

185
00:07:13,260 --> 00:07:10,509
cools off things accrete another

186
00:07:15,450 --> 00:07:13,270
molecule creates or atom treats and you

187
00:07:17,309 --> 00:07:15,460
may roam around and get together and

188
00:07:19,680 --> 00:07:17,319

react this actually turns out to be how

189
00:07:21,290 --> 00:07:19,690
you make most of the more complex

190
00:07:24,360 --> 00:07:21,300
molecules in the universe

191
00:07:26,580 --> 00:07:24,370
this concentrates everything down so if

192
00:07:28,110 --> 00:07:26,590
you're going a month between colliding

193
00:07:30,330 --> 00:07:28,120
with things it takes a long time to

194
00:07:32,969 --> 00:07:30,340
build up anything more complex than say

195
00:07:34,890 --> 00:07:32,979
methanol but if you you put everything

196
00:07:36,089 --> 00:07:34,900
down on a tiny little grain of gas and

197
00:07:38,189 --> 00:07:36,099
dust and let them roam around together

198
00:07:40,290 --> 00:07:38,199
it concentrates them it catalyzes

199
00:07:42,659 --> 00:07:40,300
reactions and you can build much bigger

200
00:07:44,399 --> 00:07:42,669
and more complex things so we'll hear a

201
00:07:46,620 --> 00:07:44,409
lot about both of these today

202
00:07:49,950 --> 00:07:46,630
to give you an idea of sort of the state

203
00:07:52,529 --> 00:07:49,960
of the field this is I think as of a few

204
00:07:54,059 --> 00:07:52,539
months ago pretty accurate this is every

205
00:07:57,180 --> 00:07:54,069
molecule we've ever found in space

206
00:07:59,159 --> 00:07:57,190
there's only about 200 of them if you'll

207
00:08:01,709 --> 00:07:59,169
notice it's really heavily weighted to

208
00:08:05,370 --> 00:08:01,719
you know really light stuff it turns out

209
00:08:07,409 --> 00:08:05,380
that seeing molecules you know twenty

210
00:08:11,249 --> 00:08:07,419
and thirty light years away or further

211
00:08:13,230 --> 00:08:11,259
is really difficult and so the bigger

212
00:08:16,110 --> 00:08:13,240
they are the harder they are to detect

213
00:08:19,890 --> 00:08:16,120

not just to make but to detect and and

214
00:08:22,409 --> 00:08:19,900
so what you see is yeah diatomics are

215
00:08:24,089 --> 00:08:22,419
pretty easy try tommix but as you get up

216
00:08:26,999 --> 00:08:24,099
to and this is what we would call

217
00:08:29,159 --> 00:08:27,009
complex anything over six atoms it gets

218
00:08:31,819 --> 00:08:29,169
very difficult and the the numbers start

219
00:08:33,870 --> 00:08:31,829
dropping off quick and so anybody that's

220
00:08:36,029 --> 00:08:33,880
reading really quickly will notice

221
00:08:37,889 --> 00:08:36,039
glycines not on here a lie seems like

222
00:08:41,699 --> 00:08:37,899
there are no sugars on here there are no

223
00:08:43,439 --> 00:08:41,709
amino acids on here the really basic

224
00:08:45,329 --> 00:08:43,449
interesting stuff you would like us to

225
00:08:48,269 --> 00:08:45,339
be able to tell you about we still can't

226
00:08:49,350 --> 00:08:48,279
find which is a little tough but it

227
00:08:51,750 --> 00:08:49,360
means that we have to lean more heavily

228
00:08:53,550 --> 00:08:51,760
on things that we can do like simulate

229
00:08:55,970 --> 00:08:53,560
the chemistry that makes everything here

230
00:08:58,950 --> 00:08:55,980
and use that too and for

231
00:09:02,160 --> 00:08:58,960
abundances we can't see but this is kind

232
00:09:03,480 --> 00:09:02,170
of state-of-the-art so just to give you

233
00:09:06,060 --> 00:09:03,490
sort of a brief overview of what

234
00:09:08,760 --> 00:09:06,070
astrochemistry ends up doing i so

235
00:09:10,890 --> 00:09:08,770
laboratory astrophysics astro chemical

236
00:09:12,420 --> 00:09:10,900
modeling and observational astronomy are

237
00:09:15,030 --> 00:09:12,430
the three sort of pillars of

238
00:09:16,950 --> 00:09:15,040

astrochemistry i will here talks mostly

239
00:09:19,140 --> 00:09:16,960
today in these two sections so

240
00:09:21,270 --> 00:09:19,150
laboratory astrophysics that's where you

241
00:09:23,580 --> 00:09:21,280
you measure spectra that lets you

242
00:09:25,410 --> 00:09:23,590
interpret your results it gives you all

243
00:09:27,330 --> 00:09:25,420
the parameters or hopefully a lot of the

244
00:09:29,940 --> 00:09:27,340
parameters for your chemical models

245
00:09:32,580 --> 00:09:29,950
kinetics thermodynamics cross-sections

246
00:09:34,500 --> 00:09:32,590
things like that astro chemical modeling

247
00:09:35,940 --> 00:09:34,510
is generally how you would interpret a

248
00:09:38,160 --> 00:09:35,950
lot of the results you model the

249
00:09:39,780 --> 00:09:38,170
observations you see you model them

250
00:09:41,760 --> 00:09:39,790
forward in time to figure out what's

251
00:09:43,350 --> 00:09:41,770
going on you can use them to think about

252
00:09:45,870 --> 00:09:43,360
what are the likely abundances of things

253
00:09:47,730 --> 00:09:45,880
you can't detect so far and then

254
00:09:49,830 --> 00:09:47,740
observational astronomy is sort of the

255
00:09:52,230 --> 00:09:49,840
stupid check on all of this what's

256
00:09:56,280 --> 00:09:52,240
actually there how much of it's there

257
00:09:57,240 --> 00:09:56,290
and where is it so a lot of the front of

258
00:09:59,280 --> 00:09:57,250
progress has been made in the last

259
00:10:01,950 --> 00:09:59,290
couple years with things like Alma we've

260
00:10:02,970 --> 00:10:01,960
heard about and so a lot of what we're

261
00:10:06,030 --> 00:10:02,980
going to be hearing about today is

262
00:10:08,010 --> 00:10:06,040
trying to figure out interpret a lot of

263
00:10:11,520 --> 00:10:08,020

the observational results that already

264
00:10:15,690 --> 00:10:11,530
exist today and so yeah this is pretty

265
00:10:17,310 --> 00:10:15,700
much how we do astrochemistry alright so

266
00:10:19,440 --> 00:10:17,320
that's that's it that's all i've got i

267
00:10:22,980 --> 00:10:19,450
just want to hurry up and get out of the

268
00:10:22,990 --> 00:10:29,139
[Applause]

269
00:10:43,119 --> 00:10:40,519
questions about astrochemistry uh why

270
00:10:47,269 --> 00:10:43,129
bigger molecules are harder to detect

271
00:10:48,740 --> 00:10:47,279
two things one so I mean even on a grain

272
00:10:50,990 --> 00:10:48,750
surface it takes a while for stuff to

273
00:10:52,160 --> 00:10:51,000
find each other and in the gas phase

274
00:10:54,679 --> 00:10:52,170
collisions are slow

275
00:10:56,720 --> 00:10:54,689
so basically statistically it just takes

276
00:10:58,340 --> 00:10:56,730
a while to build stuff up also if it

277
00:11:00,259 --> 00:10:58,350
takes a while to build stuff up it's

278
00:11:01,369 --> 00:11:00,269
much easier to tear it down so a lot of

279
00:11:06,350 --> 00:11:01,379
well we'll hear about today's photo

280
00:11:07,730 --> 00:11:06,360
destruction and bigger stuff just if it

281
00:11:09,920 --> 00:11:07,740
takes a while to build it up it gets

282
00:11:12,290 --> 00:11:09,930
blasted apart faster or not faster but

283
00:11:14,139 --> 00:11:12,300
it gets blasted apart fast compared to

284
00:11:17,360 --> 00:11:14,149
how long it takes to make it also

285
00:11:18,679 --> 00:11:17,370
heavier stuff is just the signal gets

286
00:11:22,189 --> 00:11:18,689
weaker because instead of just having

287
00:11:24,619 --> 00:11:22,199
like two states that are occupied for a

288
00:11:26,240 --> 00:11:24,629

rotational transition you get like two

289
00:11:28,309 --> 00:11:26,250
thousand states that are occupied and

290
00:11:30,079 --> 00:11:28,319
you have you know less molecules spread

291
00:11:34,730 --> 00:11:30,089
over more states it's tough to detect a

292
00:11:35,900 --> 00:11:34,740
single one so yeah big is bad but big is

293
00:11:41,259 --> 00:11:35,910
good because that's where all the

294
00:11:46,490 --> 00:11:41,269
complex stuff is any more questions