2017 Astrobiology Graduate Conference

1
00:00:00,790 --> 00:00:08,110
[Music]

2
00:00:12,049 --> 00:00:10,970
as has been mentioned I'm going to tell

3
00:00:15,919 --> 00:00:12,059
you a little bit more about radiation

4
00:00:18,650 --> 00:00:15,929
and I talk which is subtitled cosmic

5
00:00:26,960 --> 00:00:18,660
rays bite the dust so hopefully you'll

6
00:00:34,490 --> 00:00:26,970
see why in a bit all right I can advance

7
00:00:36,889 --> 00:00:34,500
this slide all right so in order to talk

8
00:00:39,170 --> 00:00:36,899
about radiation chemistry and radiation

9
00:00:41,900 --> 00:00:39,180
chemical processes we have to talk about

10
00:00:44,959 --> 00:00:41,910
stopping theory so what do we mean by

11
00:00:47,900 --> 00:00:44,969
stopping theory well I'll get around to

12
00:00:49,970 --> 00:00:47,910
it well kind of do its OOP circuitous

13
00:00:54,110 --> 00:00:49,980

route first we'll start with a

14
00:00:58,090 --> 00:00:54,120
historical overview in 1896 all Rebecca

15
00:01:00,470 --> 00:00:58,100
rel discovered radioactivity except a

16
00:01:03,020 --> 00:01:00,480
they didn't know that it was

17
00:01:05,390 --> 00:01:03,030
radioactivity and it wasn't called

18
00:01:07,700 --> 00:01:05,400
radioactivity what beck rail found was

19
00:01:09,440 --> 00:01:07,710
that uranium salts were messing up his

20
00:01:11,570 --> 00:01:09,450
photographic plates well he was doing

21
00:01:13,640 --> 00:01:11,580
experiments and he thought they were

22
00:01:15,530 --> 00:01:13,650
making x-rays turns out they're making

23
00:01:19,100 --> 00:01:15,540
something which were called immediately

24
00:01:22,070 --> 00:01:19,110
afterwards Becquerel rays and later in

25
00:01:24,109 --> 00:01:22,080
1998 Marie Curie and Pierre Curie

26
00:01:27,499 --> 00:01:24,119
started working on this they called it

27
00:01:30,230 --> 00:01:27,509
radioactivity and Marie Curie made the

28
00:01:32,120 --> 00:01:30,240
very astute observation that the Alpha

29
00:01:34,420 --> 00:01:32,130
rays that she was seeing were losing

30
00:01:36,800 --> 00:01:34,430
velocity as they traveled through matter

31
00:01:39,289 --> 00:01:36,810
one of the remarkable things about this

32
00:01:41,690 --> 00:01:39,299
observation is that she made it before

33
00:01:44,359 --> 00:01:41,700
we had the modern model of atomic

34
00:01:46,429 --> 00:01:44,369
structure so they had no idea what alpha

35
00:01:48,710 --> 00:01:46,439
rays were or how they could be losing

36
00:01:51,340 --> 00:01:48,720
matter they just knew that from

37
00:01:55,340 --> 00:01:51,350
experiments that's what they were doing

38
00:01:56,810 --> 00:01:55,350

all right moving a little bit forward in

39
00:01:59,780 --> 00:01:56,820
time to 1912

40
00:02:01,399 --> 00:01:59,790
JJ Thompson discovers the electron or he

41
00:02:03,350 --> 00:02:01,409
discovered the electron previously and

42
00:02:06,289 --> 00:02:03,360
then in that year he wrote the first

43
00:02:09,830 --> 00:02:06,299
theoretical paper on the how charged

44
00:02:11,690 --> 00:02:09,840
particles lose energy now the field has

45
00:02:16,330 --> 00:02:11,700
evolved a bit but we still use a lot of

46
00:02:20,720 --> 00:02:18,350
and in 1913

47
00:02:23,150 --> 00:02:20,730
niels bohr wrote a paper with the very

48
00:02:25,280 --> 00:02:23,160
short title on the decrease of velocity

49
00:02:27,710 --> 00:02:25,290
of moving electrified particles on

50
00:02:29,720 --> 00:02:27,720
passing through matter and he swiftly

51
00:02:31,490 --> 00:02:29,730
followed it up with a paper with the

52
00:02:33,490 --> 00:02:31,500
radically different title on the

53
00:02:36,080 --> 00:02:33,500
decrease of velocity of swiftly moving

54
00:02:38,500 --> 00:02:36,090
electrified particles in passing through

55
00:02:41,210 --> 00:02:38,510
matter now these were landmark papers

56
00:02:43,430 --> 00:02:41,220
they sort of helped make his career and

57
00:02:45,920 --> 00:02:43,440
we still use a lot of the theory that he

58
00:02:47,900 --> 00:02:45,930
developed in talking about how charged

59
00:02:49,910 --> 00:02:47,910
particles lose energy here's one of the

60
00:02:51,800 --> 00:02:49,920
things which we still use a lot and is

61
00:02:53,300 --> 00:02:51,810
to divide the types of collisions which

62
00:02:55,370 --> 00:02:53,310
a charged particle and

63
00:02:58,340 --> 00:02:55,380

counters on moving through matter into

64
00:02:59,090 --> 00:02:58,350
two main categories one of them which

65
00:03:02,060 --> 00:02:59,100
one is the laser

66
00:03:04,310 --> 00:03:02,070
there's laser conveniently colored and

67
00:03:06,380 --> 00:03:04,320
we call nuclear or elastic collisions

68
00:03:08,630 --> 00:03:06,390
and this is when the charged particle is

69
00:03:11,210 --> 00:03:08,640
losing energy to the nuclei in what we

70
00:03:13,250 --> 00:03:11,220
call the target the other is called

71
00:03:14,840 --> 00:03:13,260
electronic or inelastic collisions and

72
00:03:17,180 --> 00:03:14,850
this is when the charged particle is

73
00:03:21,890 --> 00:03:17,190
losing energy to the electrons so this

74
00:03:23,630 --> 00:03:21,900
comes from Bohr and we still use it so

75
00:03:27,110 --> 00:03:23,640
finally in our historical overview in

76
00:03:29,449 --> 00:03:27,120
1932 Hans bethe applied the very latest

77
00:03:32,420 --> 00:03:29,459
in quantum mechanics and relativity to

78
00:03:34,160 --> 00:03:32,430
stopping theory and the bethe

79
00:03:37,250 --> 00:03:34,170
formula for stopping power is still

80
00:03:39,830 --> 00:03:37,260
widely used oh okay now that works right

81
00:03:41,780 --> 00:03:39,840
so now that I've told you about how the

82
00:03:43,280 --> 00:03:41,790
theory of stopping power has developed

83
00:03:44,630 --> 00:03:43,290
I'm going to tell you what it looks like

84
00:03:48,110 --> 00:03:44,640
when you put all the physical processes

85
00:03:50,030 --> 00:03:48,120
together and so you can divide the

86
00:03:52,430 --> 00:03:50,040
timeline of what happens when a particle

87
00:03:55,070 --> 00:03:52,440
is moving through some matter into three

88
00:03:57,590 --> 00:03:55,080

main stages so in this first stage the

89
00:03:58,190 --> 00:03:57,600
physical stage molecules are ionized and

90
00:04:01,490 --> 00:03:58,200
excited

91
00:04:03,290 --> 00:04:01,500
this is very fast and so what happens is

92
00:04:05,690 --> 00:04:03,300
you produce a lot of charged species and

93
00:04:08,270 --> 00:04:05,700
species in electronically excited States

94
00:04:12,680 --> 00:04:08,280
which go on in the physicochemical stage

95
00:04:15,250 --> 00:04:12,690
to recombine electronically so charges

96
00:04:17,719 --> 00:04:15,260
are neutralized and this results in

97
00:04:21,080 --> 00:04:17,729
dissociations and then some of the

98
00:04:23,060 --> 00:04:21,090
excited species can also dissociate when

99
00:04:25,219 --> 00:04:23,070
you're talking about radiation and

100
00:04:27,110 --> 00:04:25,229
solids species on or near the surface

101
00:04:29,120 --> 00:04:27,120
can also get kicked off

102
00:04:32,450 --> 00:04:29,130
process called sputtering which is very

103
00:04:34,460 --> 00:04:32,460
complicated so in the physicochemical

104
00:04:37,370 --> 00:04:34,470
stage what you're left with are a bunch

105
00:04:39,770 --> 00:04:37,380
of really reactive fragments and

106
00:04:41,900 --> 00:04:39,780
radicals and they can do chemistry in

107
00:04:44,990 --> 00:04:41,910
the chemical stage so you'll notice this

108
00:04:48,170 --> 00:04:45,000
is the longest it's also been the

109
00:04:50,480 --> 00:04:48,180
hardest to simulate but in this case

110
00:04:52,010 --> 00:04:50,490
what happens is at least in solids the

111
00:04:53,960 --> 00:04:52,020
species that you've made you can sort of

112
00:04:55,700 --> 00:04:53,970
move around as you saw in Brandon's talk

113
00:04:58,040 --> 00:04:55,710

and if they encounter one another and

114
00:05:02,870 --> 00:04:58,050
can react they can do so and form

115
00:05:05,689 --> 00:05:02,880
strange new molecules alright so here's

116
00:05:07,820 --> 00:05:05,699
what it looks like all together now

117
00:05:09,710 --> 00:05:07,830
for reasons which will become hopefully

118
00:05:12,290 --> 00:05:09,720
obvious later on imagine that this blue

119
00:05:14,750 --> 00:05:12,300
block is an o2 ice and you've got a

120
00:05:17,270 --> 00:05:14,760
proton coming in and what happens well

121
00:05:20,500 --> 00:05:17,280
as I mentioned during the physical stage

122
00:05:23,180 --> 00:05:20,510
it can ionize species or excite them and

123
00:05:26,029 --> 00:05:23,190
these electrons produced in the

124
00:05:29,659 --> 00:05:26,039
ionizations are referred to as secondary

125
00:05:31,700 --> 00:05:29,669
electrons confusingly here electron a is

126
00:05:33,920 --> 00:05:31,710
called a first generation secondary

127
00:05:37,060 --> 00:05:33,930
electron and if it has enough energy it

128
00:05:40,159 --> 00:05:37,070
can go on and further ini species

129
00:05:42,050 --> 00:05:40,169
creating also confusingly what's known

130
00:05:45,770 --> 00:05:42,060
as a second generation secondary

131
00:05:47,659 --> 00:05:45,780
electron and these can excite species as

132
00:05:49,250 --> 00:05:47,669
well now when they lose enough energy

133
00:05:50,900 --> 00:05:49,260
through collisions these secondary

134
00:05:53,810 --> 00:05:50,910
electrons enter what's called the sub

135
00:05:55,580 --> 00:05:53,820
excitation regime and can do strange and

136
00:05:58,790 --> 00:05:55,590
bizarre things like where you can have a

137
00:06:01,430 --> 00:05:58,800
for evey electron breaking a 5e v bond

138
00:06:06,500 --> 00:06:01,440

thanks to the magic of potential

139
00:06:07,700 --> 00:06:06,510
surfaces all right so that's track

140
00:06:09,260 --> 00:06:07,710
structure now I'm going to tell you a

141
00:06:10,909 --> 00:06:09,270
little bit about a new model I wrote

142
00:06:12,830 --> 00:06:10,919
which can do the physical the

143
00:06:17,270 --> 00:06:12,840
physicochemical and the chemical stages

144
00:06:19,370 --> 00:06:17,280
of irradiation is called serous serous

145
00:06:22,879 --> 00:06:19,380
it's not Chris that would be a little

146
00:06:25,490 --> 00:06:22,889
bit too vain it stands for the chemistry

147
00:06:27,020 --> 00:06:25,500
of ionizing radiation and solids as you

148
00:06:28,700 --> 00:06:27,030
can see I could have called it Chris but

149
00:06:32,900 --> 00:06:28,710
that would have been a little bit too

150
00:06:34,760 --> 00:06:32,910
too rich so it's the microscopic Monte

151
00:06:36,469 --> 00:06:34,770
Carlo model which as far as I know is

152
00:06:38,600 --> 00:06:36,479
the first one which is able to combine

153
00:06:40,700 --> 00:06:38,610
the atomic physics calculations again

154
00:06:41,480 --> 00:06:40,710
and the chemistry they're able to do

155
00:06:43,100 --> 00:06:41,490
that long

156
00:06:46,490 --> 00:06:43,110
cool phase as well where you have things

157
00:06:48,100 --> 00:06:46,500
moving around and so again we use the

158
00:06:50,600 --> 00:06:48,110
kinetic Monte Carlo method for that

159
00:06:54,260 --> 00:06:50,610
here's the paper recently came out where

160
00:06:56,210 --> 00:06:54,270
I described it and just as a quick side

161
00:06:59,180 --> 00:06:56,220
note the model was written in Fortran is

162
00:07:02,480 --> 00:06:59,190
a matter of local pride that I have to

163
00:07:04,610 --> 00:07:02,490

mention that in 1956 the Fortran project

164
00:07:08,020 --> 00:07:04,620
at IBM was headed by this fellow John

165
00:07:10,719 --> 00:07:08,030
Backus who was a UVA chemistry undergrad

166
00:07:15,710 --> 00:07:10,729
just a little bit of Fortran trivia

167
00:07:18,140 --> 00:07:15,720
alright back to the science so in trying

168
00:07:22,070 --> 00:07:18,150
to simulate tracks my initial attempts

169
00:07:24,469 --> 00:07:22,080
were not very impressive so what do we

170
00:07:27,140 --> 00:07:24,479
have here well imagine you have an o2

171
00:07:29,839 --> 00:07:27,150
ice and you have a proton entering right

172
00:07:31,520 --> 00:07:29,849
here it's moving through and randomly

173
00:07:33,710 --> 00:07:31,530
since this is a Monte Carlo model it's

174
00:07:35,809 --> 00:07:33,720
having collisions and so these points

175
00:07:38,719 --> 00:07:35,819
represent either elastic collisions or

176
00:07:42,469 --> 00:07:38,729
inelastic collisions or which can be

177
00:07:44,120 --> 00:07:42,479
ionization of excitations so that's nice

178
00:07:45,770 --> 00:07:44,130
and I was certainly very happy when my

179
00:07:49,219 --> 00:07:45,780
model started to do something I wanted

180
00:07:51,589 --> 00:07:49,229
it to do but it's not very impressive so

181
00:07:54,170 --> 00:07:51,599
you may be slightly more impressed with

182
00:08:06,290 --> 00:07:54,180
what we can do currently if I can get

183
00:08:21,960 --> 00:08:17,280
uh-huh okay there you go all right so so

184
00:08:26,280 --> 00:08:21,970
here's what we have now circa 2017 what

185
00:08:31,770 --> 00:08:26,290
we have is similar to the first plot I

186
00:08:34,050 --> 00:08:31,780
showed you I'll replay that you have a

187
00:08:36,330 --> 00:08:34,060
particle coming in here a proton moving

188
00:08:38,520 --> 00:08:36,340

through your o2 ice except now you can

189
00:08:42,090 --> 00:08:38,530
see all of the secondary electron tracks

190
00:08:44,580 --> 00:08:42,100
so these meander around randomly and do

191
00:08:47,040 --> 00:08:44,590
those excitation and ionization 's and

192
00:08:49,260 --> 00:08:47,050
in those funny things they do and they

193
00:08:55,110 --> 00:08:49,270
lose enough energy so we can do a little

194
00:09:01,780 --> 00:08:55,120
bit better today all right back to

195
00:09:08,170 --> 00:09:04,060
theorists are the worst at using

196
00:09:12,700 --> 00:09:08,180
technology sometimes alright so yes so

197
00:09:14,050 --> 00:09:12,710
there it is so now I'll finally tell you

198
00:09:15,880 --> 00:09:14,060
why I've been talking about Oh to ice

199
00:09:17,710 --> 00:09:15,890
and that's because chemically for an

200
00:09:21,310 --> 00:09:17,720
irradiation for an irradiated system

201
00:09:23,830 --> 00:09:21,320
it's about as simple as you can get so

202
00:09:26,140 --> 00:09:23,840
we found this experiment it we wanted to

203
00:09:29,500 --> 00:09:26,150
simulate a well constrained experiment

204
00:09:32,590 --> 00:09:29,510
rather than the fairly well

205
00:09:34,240 --> 00:09:32,600
unconstrained interstellar medium and so

206
00:09:34,630 --> 00:09:34,250
we found this one which was done here at

207
00:09:36,250 --> 00:09:34,640
UVA

208
00:09:42,460 --> 00:09:36,260
that wasn't a requirement but it was

209
00:09:45,010 --> 00:09:42,470
certainly a perk where OSA our oxygen

210
00:09:47,710 --> 00:09:45,020
ice was irradiated with 100 kV protons

211
00:09:49,990 --> 00:09:47,720
and ozone was synthesized that the ice

212
00:09:52,290 --> 00:09:50,000
was kept at 5 Kelvin under ultra-high

213
00:09:55,210 --> 00:09:52,300

vacuum and was about 10 microns thick

214
00:09:58,360 --> 00:09:55,220
keep this number in the back of your

215
00:10:00,670 --> 00:09:58,370
mind all right so here's our $64,000

216
00:10:02,050 --> 00:10:00,680
question once we have the tracks could

217
00:10:03,790 --> 00:10:02,060
we combine it with the chemical model

218
00:10:06,700 --> 00:10:03,800
and actually do chemistry this was the

219
00:10:08,890 --> 00:10:06,710
part which had never been done before so

220
00:10:10,750 --> 00:10:08,900
let's talk about our chemical model a

221
00:10:12,640 --> 00:10:10,760
Monte Carlo model is a little bit like

222
00:10:15,700 --> 00:10:12,650
waiting in line to board a plane it's

223
00:10:19,570 --> 00:10:15,710
like the snow rate and a game of

224
00:10:20,950 --> 00:10:19,580
three-dimensional chess all right so how

225
00:10:24,490 --> 00:10:20,960
is it like a game of three-dimensional

226
00:10:26,230 --> 00:10:24,500
chess well this is just a more detailed

227
00:10:28,960 --> 00:10:26,240
version of what you saw earlier in

228
00:10:31,510 --> 00:10:28,970
Brandon's talk you can have imagine this

229
00:10:33,520 --> 00:10:31,520
is looking down from an aliens eye view

230
00:10:35,800 --> 00:10:33,530
on the surface of an ice you can have

231
00:10:38,350 --> 00:10:35,810
things coming in from the gas phase onto

232
00:10:40,150 --> 00:10:38,360
the grain dis orbing or hopping around

233
00:10:43,600 --> 00:10:40,160
and again if they encounter a co

234
00:10:45,280 --> 00:10:43,610
reactant they can react and then imagine

235
00:10:48,570 --> 00:10:45,290
this being sort of a dull house top to

236
00:10:51,700 --> 00:10:48,580
bottom slice and the yellow the blue

237
00:10:53,380 --> 00:10:51,710
squares represent lattice sites we would

238
00:10:55,810 --> 00:10:53,390

call them normal sites and the yellow

239
00:10:57,640 --> 00:10:55,820
squares are interstitial sites and these

240
00:10:59,470 --> 00:10:57,650
enable diffusion through out the solid

241
00:11:01,150 --> 00:10:59,480
so as you see here things can move

242
00:11:04,180 --> 00:11:01,160
around and react when they encounter a

243
00:11:05,980 --> 00:11:04,190
co reactant that's just a simple picture

244
00:11:07,860 --> 00:11:05,990
of how it's like a three-dimensional

245
00:11:10,360 --> 00:11:07,870
chess game so putting it all together

246
00:11:12,730 --> 00:11:10,370
here's the basic algorithm of the cirrus

247
00:11:14,380 --> 00:11:12,740
model so when you start your program the

248
00:11:15,190 --> 00:11:14,390
first thing which happens is it gets

249
00:11:17,830 --> 00:11:15,200
smacked with the pro

250
00:11:19,830 --> 00:11:17,840
on and so you calculate the track then

251
00:11:22,510 --> 00:11:19,840
you evaluate your ending condition and

252
00:11:24,160 --> 00:11:22,520
if the model isn't over yet you go back

253
00:11:25,960 --> 00:11:24,170
and figure out what the next thing is

254
00:11:27,850 --> 00:11:25,970
since it's a Monte Carlo model

255
00:11:29,590 --> 00:11:27,860
everything has to wait for everything

256
00:11:31,600 --> 00:11:29,600
else only one thing can happen at a time

257
00:11:34,240 --> 00:11:31,610
and you just keep going through this

258
00:11:36,790 --> 00:11:34,250
loop until you reach your exit condition

259
00:11:38,140 --> 00:11:36,800
but now when a neutral species hops this

260
00:11:40,030 --> 00:11:38,150
is where the chemistry happens because

261
00:11:42,190 --> 00:11:40,040
as I mentioned if it encounters

262
00:11:45,100 --> 00:11:42,200
something it can react with you form a

263
00:11:47,140 --> 00:11:45,110

new product so we have the chemistry

264
00:11:49,390 --> 00:11:47,150
over here we have the track calculations

265
00:11:54,010 --> 00:11:49,400
over here it combines all together into

266
00:11:54,340 --> 00:11:54,020
a model which can do some cool stuff all

267
00:11:58,150 --> 00:11:54,350
right

268
00:12:01,870 --> 00:11:58,160
so chemistry as I mentioned the o2

269
00:12:04,330 --> 00:12:01,880
system you can think of it as having a

270
00:12:06,520 --> 00:12:04,340
fairly simple chemistry you have your o2

271
00:12:09,970 --> 00:12:06,530
getting broken apart by X here meaning

272
00:12:12,370 --> 00:12:09,980
radiation and two two oxygen atoms those

273
00:12:15,310 --> 00:12:12,380
oxygen atoms can combine with molecular

274
00:12:17,740 --> 00:12:15,320
oxygen to form ozone stable stabilized

275
00:12:20,830 --> 00:12:17,750
by a third body the ozone can get broken

276
00:12:24,610 --> 00:12:20,840
apart and can also react with oxygen so

277
00:12:26,230 --> 00:12:24,620
it looks like a fairly simple system but

278
00:12:28,180 --> 00:12:26,240
now this is from the point of view of a

279
00:12:29,830 --> 00:12:28,190
typical rate equations type chemical

280
00:12:31,780 --> 00:12:29,840
model what does it look like from the

281
00:12:33,060 --> 00:12:31,790
point of view of a detailed Monte Carlo

282
00:12:36,670 --> 00:12:33,070
based model where you're dealing with

283
00:12:38,710 --> 00:12:36,680
excited species and ionized species so

284
00:12:40,510 --> 00:12:38,720
here is the reactions table from our

285
00:12:42,730 --> 00:12:40,520
paper we have more than an order of

286
00:12:44,700 --> 00:12:42,740
magnitude more reactions than that

287
00:12:48,580 --> 00:12:44,710
simple system that I showed you before

288
00:12:50,500 --> 00:12:48,590

we have as I mentioned we have ions we

289
00:12:52,690 --> 00:12:50,510
have excited species and these become

290
00:12:54,940 --> 00:12:52,700
very useful in actually doing the

291
00:12:57,960 --> 00:12:54,950
chemistry because you have to make a lot

292
00:13:01,450 --> 00:12:57,970
of approximations in this sort of regime

293
00:13:04,630 --> 00:13:01,460
so I beating around the bush but here

294
00:13:07,150 --> 00:13:04,640
are our final results here is ozone

295
00:13:09,250 --> 00:13:07,160
concentration here's fluids fluence just

296
00:13:11,980 --> 00:13:09,260
means how many particles you smacked

297
00:13:15,250 --> 00:13:11,990
into your solid and you can see in our

298
00:13:17,800 --> 00:13:15,260
blue are the experimental data in yellow

299
00:13:19,570 --> 00:13:17,810
we have our standard model results and

300
00:13:22,690 --> 00:13:19,580
you can see we get the steady state

301
00:13:24,190 --> 00:13:22,700
chemists Bundys of ozone early well so

302
00:13:25,690 --> 00:13:24,200
we were happy about this but we noticed

303
00:13:28,480 --> 00:13:25,700
we were at higher fluencies than the

304
00:13:28,879 --> 00:13:28,490
experiment so we thought about it a

305
00:13:30,609 --> 00:13:28,889
little bit

306
00:13:33,319 --> 00:13:30,619
and realized oh it's probably because

307
00:13:35,840 --> 00:13:33,329
what we're doing this is a thinner ice

308
00:13:37,460 --> 00:13:35,850
than the experiment actually used so

309
00:13:39,650 --> 00:13:37,470
you're depositing less energy per

310
00:13:42,739 --> 00:13:39,660
particle into it and making less ozone

311
00:13:44,689 --> 00:13:42,749
per particle so this was a point one

312
00:13:47,389 --> 00:13:44,699
micron ice we simulated the effects of

313
00:13:49,759 --> 00:13:47,399

having a 1 and 10 micron ice and the 10

314
00:13:53,119 --> 00:13:49,769
micron ice reproduced the experimental

315
00:13:54,979 --> 00:13:53,129
data very nicely and as you remember

316
00:13:57,229 --> 00:13:54,989
from the earlier slide the experimental

317
00:13:58,879 --> 00:13:57,239
ice was about 10 microns so not only do

318
00:14:01,189 --> 00:13:58,889
we predict the steady-state abundance

319
00:14:03,319 --> 00:14:01,199
but we also are able to roughly predict

320
00:14:07,159 --> 00:14:03,329
the thickness of the ice so we are very

321
00:14:10,369 --> 00:14:07,169
happy about that all right so with that

322
00:14:12,729 --> 00:14:10,379
I'd like to thank my advisor former

323
00:14:16,519 --> 00:14:12,739
fellow group members collaborators and

324
00:14:36,720 --> 00:14:16,529
I'll leave you with this last slide from

325
00:14:42,579 --> 00:14:39,699
this may be a very nice question but so

326
00:14:44,650 --> 00:14:42,589
in your we had your proton that hits

327
00:14:48,129 --> 00:14:44,660
your eyes we have all these tracks they

328
00:14:50,439 --> 00:14:48,139
seem to have the same width I was

329
00:14:53,410 --> 00:14:50,449
wondering if you have more energy when

330
00:14:56,439 --> 00:14:53,420
you come in you have more secondary

331
00:14:59,110 --> 00:14:56,449
electrons and we will be larger at the

332
00:14:59,740 --> 00:14:59,120
beginning and yell again yeah that's a

333
00:15:10,269 --> 00:14:59,750
good question

334
00:15:12,069 --> 00:15:10,279
so the will go back so there's a funny

335
00:15:14,790 --> 00:15:12,079
relationship where the higher the energy

336
00:15:17,139 --> 00:15:14,800
of the primary particle coming in the

337
00:15:18,610 --> 00:15:17,149
smaller the cross-section so the fewer

338
00:15:21,400 --> 00:15:18,620

secondary electrons they're going to

339
00:15:24,360 --> 00:15:21,410
make now the sort of width of this is

340
00:15:27,579 --> 00:15:24,370
actually determined by the average

341
00:15:30,040 --> 00:15:27,589
secondary electron energy now you can

342
00:15:31,960 --> 00:15:30,050
get very energetic electrons coming off

343
00:15:35,559 --> 00:15:31,970
this as well those are called delta rays

344
00:15:36,939 --> 00:15:35,569
and so since this is random you see some

345
00:15:39,100 --> 00:15:36,949
of them don't go very far some of them

346
00:15:41,110 --> 00:15:39,110
have more energy so since this is a

347
00:15:43,120 --> 00:15:41,120
stochastic model you get the luck of the

348
00:15:47,019 --> 00:15:43,130
draw but this is as it is in nature as

349
00:15:48,699 --> 00:15:47,029
well it's based on the average electron

350
00:15:54,610 --> 00:15:48,709
energy which is sort of a skewed

351
00:15:56,230 --> 00:15:54,620
Gaussian type distribution all right

352
00:15:59,019 --> 00:15:56,240
Chris I got a question for you cool so

353
00:16:01,930 --> 00:15:59,029
can you do this with a water ice yes

354
00:16:03,370 --> 00:16:01,940
there's a so we just that's one of the

355
00:16:05,829 --> 00:16:03,380
next things that we're looking to do is

356
00:16:07,569 --> 00:16:05,839
water ice because clearly water ice is

357
00:16:10,059 --> 00:16:07,579
the most astrophysically relevant ice

358
00:16:12,389 --> 00:16:10,069
and so the reason why we didn't want to

359
00:16:14,410 --> 00:16:12,399
do this water ice first is because

360
00:16:20,199 --> 00:16:14,420
hydrogen's make everything complicated

361
00:16:22,179 --> 00:16:20,209
and Oh two is relatively simple as you

362
00:16:25,030 --> 00:16:22,189
saw at least in the rate equations type

363
00:16:26,740 --> 00:16:25,040

approach so that's the next step

364
00:16:29,110 --> 00:16:26,750
my follow-up is what happens when you

365
00:16:31,420 --> 00:16:29,120
add desk to when you add us to so you

366
00:16:33,220 --> 00:16:31,430
mean a physical surface underneath the

367
00:16:36,009 --> 00:16:33,230
ice with more stopping power with more

368
00:16:39,370 --> 00:16:36,019
stopping power so what happens is there

369
00:16:41,170 --> 00:16:39,380
are some cases where because the dust

370
00:16:43,840 --> 00:16:41,180
grains are just on average point 1

371
00:16:45,699 --> 00:16:43,850
microns in diameter you're not going to

372
00:16:47,320 --> 00:16:45,709
lose a lot of energy if you have say 100

373
00:16:49,000 --> 00:16:47,330
kV proton you can try

374
00:16:51,639 --> 00:16:49,010
through the dusk rain come out the other

375
00:16:53,970 --> 00:16:51,649
side and sort of them bar the other side

376
00:16:56,980 --> 00:16:53,980
of the ice so there will be cases where

377
00:16:59,230 --> 00:16:56,990
the cosmic ray will bite the dust and in

378
00:17:01,120 --> 00:16:59,240
those cases you can actually completely

379
00:17:03,009 --> 00:17:01,130
obliterate your grain and just blast

380
00:17:05,980 --> 00:17:03,019
everything off into the gas phase which

381
00:17:07,419 --> 00:17:05,990
is an interesting thing which I am going

382
00:17:09,610 --> 00:17:07,429
to be looking at in the future at some

383
00:17:11,230 --> 00:17:09,620
point but yeah generally speaking the

384
00:17:16,559 --> 00:17:11,240
cosmic rays will just zip right through

385
00:17:18,730 --> 00:17:16,569
the dust grain they also have questions

386
00:17:19,620 --> 00:17:18,740
all right that case let's thank Chris