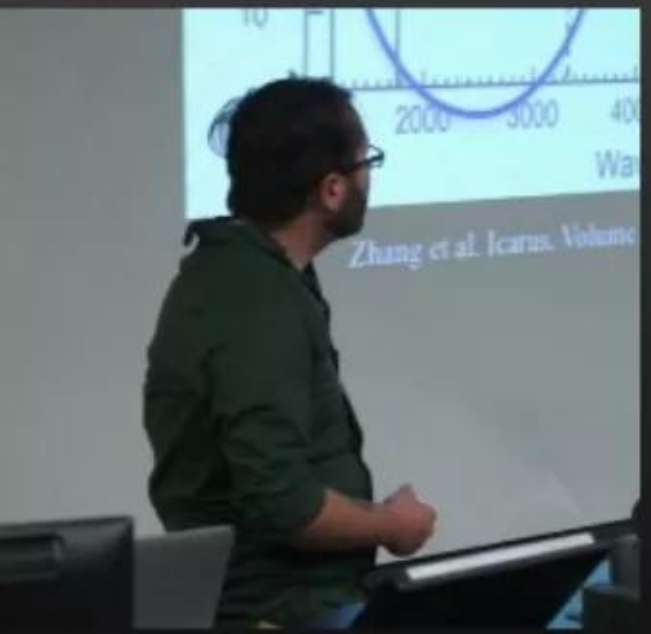
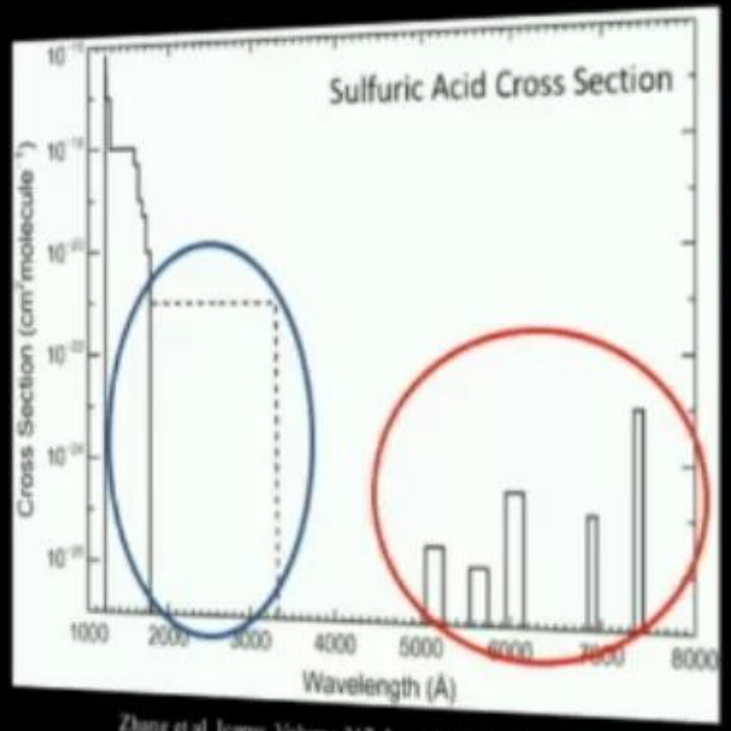
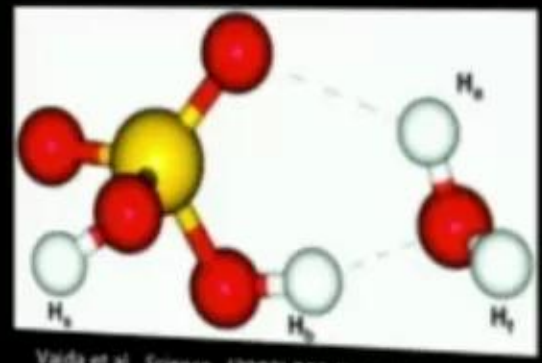
Models of Venus





Zhang et al. Icarus, Volume 217, Issue 2, 2012, 714 - 739

- Include Inaccurate UV Cross Sections
- Include Red Light Photolysis for Sulfuric Acid and Its Monohydrate



Vaida et al., *Science*, (2003).**299** (5612): 1566-1568

1
00:00:10,879 --> 00:00:09,230
yeah so I'm Jake roll and a student here

2
00:00:12,950 --> 00:00:10,889
at the University of Colorado in the

3
00:00:16,189 --> 00:00:12,960
vitae group I'm actually just across the

4
00:00:17,689 --> 00:00:16,199
way from here but I'm going to move into

5
00:00:20,349 --> 00:00:17,699
the solar system and talk more about

6
00:00:22,730 --> 00:00:20,359
Earth and Venus and about some

7
00:00:25,939 --> 00:00:22,740
photochemical formation of aerosols why

8
00:00:27,740 --> 00:00:25,949
we care about those and some work that

9
00:00:31,939 --> 00:00:27,750
I've been doing on sulfur chemistry with

10
00:00:33,889 --> 00:00:31,949
sulfur dioxide and so just to give you

11
00:00:36,650 --> 00:00:33,899
some background about why we care about

12
00:00:39,500 --> 00:00:36,660
sulfur sulfur has been observed in a

13
00:00:42,220 --> 00:00:39,510

number of planetary bodies including a

14
00:00:46,940 --> 00:00:42,230
number of the rocky planets as well as

15
00:00:49,670 --> 00:00:46,950
some moons Jovian moons and I'll be

16
00:00:54,020 --> 00:00:49,680
focusing on Venus and Earth and kind of

17
00:00:56,389 --> 00:00:54,030
the implications there and so sulfur is

18
00:00:58,580 --> 00:00:56,399
really important for climate and for

19
00:01:01,040 --> 00:00:58,590
understanding the temperature of our

20
00:01:03,110 --> 00:01:01,050
planet the energy budget the reason for

21
00:01:05,090 --> 00:01:03,120
this is in any sort of oxidizing

22
00:01:08,030 --> 00:01:05,100
atmosphere most of the sulfur that gets

23
00:01:10,340 --> 00:01:08,040
released ends up is sulfur dioxide then

24
00:01:13,820 --> 00:01:10,350
three reactions with 08 radicals goes on

25
00:01:15,710 --> 00:01:13,830
to form this HS 03 ultimately you end up

26
00:01:18,350 --> 00:01:15,720
with this so3 and threw a water

27
00:01:21,950 --> 00:01:18,360
catalyzed reaction you get so pure

28
00:01:23,090 --> 00:01:21,960
sulfuric acid and sulfuric acid is

29
00:01:25,070 --> 00:01:23,100
really important because it's this

30
00:01:28,609 --> 00:01:25,080
hygroscopic molecule it likes to take up

31
00:01:31,850 --> 00:01:28,619
water and form aerosol which is this in

32
00:01:35,719 --> 00:01:31,860
this case an aqueous droplet suspended

33
00:01:37,580 --> 00:01:35,729
in the air so in Earth's atmosphere in

34
00:01:40,340 --> 00:01:37,590
the lower atmosphere in the troposphere

35
00:01:42,260 --> 00:01:40,350
where there's a lot of water what ends

36
00:01:46,280 --> 00:01:42,270
up happening is you seed cloud and you

37
00:01:49,429 --> 00:01:46,290
get rain out and that soul and so then

38
00:01:51,080 --> 00:01:49,439

most of its depleted however in the

39
00:01:53,660 --> 00:01:51,090
upper atmosphere where there's a lot

40
00:01:54,590 --> 00:01:53,670
less water that so2 tends to stick

41
00:01:57,889 --> 00:01:54,600
around you get much higher

42
00:02:01,219 --> 00:01:57,899
concentrations of so2 and that aerosol

43
00:02:05,690 --> 00:02:01,229
rather than raining out stay suspended

44
00:02:06,889 --> 00:02:05,700
for a number of years and thus what this

45
00:02:09,499 --> 00:02:06,899
is really important because it can

46
00:02:11,150 --> 00:02:09,509
reflect away a lot of incoming solar

47
00:02:12,230 --> 00:02:11,160
radiation and change the temperature of

48
00:02:15,390 --> 00:02:12,240
the planet

49
00:02:17,160 --> 00:02:15,400
and so in earth we actually end up with

50
00:02:19,530 --> 00:02:17,170
this young galere which is a layer of

51
00:02:23,160 --> 00:02:19,540
aerosol that you can see at about 15 to

52
00:02:25,830 --> 00:02:23,170
20 kilometers in the atmosphere and you

53
00:02:28,740 --> 00:02:25,840
can see that it actually reflects away

54
00:02:30,810 --> 00:02:28,750
quite a large amount of light and

55
00:02:33,270 --> 00:02:30,820
anytime that there's a large eruption on

56
00:02:36,960 --> 00:02:33,280
earth that injects large amounts of so2

57
00:02:39,000 --> 00:02:36,970
into the stratosphere we see these large

58
00:02:40,560 --> 00:02:39,010
changes in optical depth where an

59
00:02:41,940 --> 00:02:40,570
increase in optical depth means that

60
00:02:44,280 --> 00:02:41,950
there's more light being scattered away

61
00:02:46,710 --> 00:02:44,290
and these sorts of events can have you

62
00:02:50,600 --> 00:02:46,720
know fractions of a degree Celsius

63
00:02:54,000 --> 00:02:50,610

change on the planet overall temperature

64
00:02:56,160 --> 00:02:54,010
but so if we go to Venus Venus tells us

65
00:02:58,470 --> 00:02:56,170
something pretty interesting because

66
00:03:02,220 --> 00:02:58,480
there's huge amounts of sulfur and

67
00:03:03,960 --> 00:03:02,230
Venus's atmosphere about from 50 to 70

68
00:03:07,970 --> 00:03:03,970
kilometers there's this large sulfuric

69
00:03:10,860 --> 00:03:07,980
acid clouds that cover the entire planet

70
00:03:12,840 --> 00:03:10,870
but interestingly starting at about 90

71
00:03:15,360 --> 00:03:12,850
kilometers there's a huge increase in

72
00:03:18,300 --> 00:03:15,370
so2 and sulfur monoxide concentration

73
00:03:19,980 --> 00:03:18,310
several orders of magnitude change and

74
00:03:22,380 --> 00:03:19,990
this actually exceeds any model

75
00:03:24,450 --> 00:03:22,390
predictions by multiple orders of

76
00:03:25,920 --> 00:03:24,460
magnitude and so what this tells us

77
00:03:27,810 --> 00:03:25,930
there's probably some sort of chemical

78
00:03:31,320 --> 00:03:27,820
formation of so2 in the middle

79
00:03:32,610 --> 00:03:31,330
atmosphere of Venus but what's really

80
00:03:34,410 --> 00:03:32,620
interesting about this is that these

81
00:03:36,060 --> 00:03:34,420
conditions are very similar to Earth's

82
00:03:37,320 --> 00:03:36,070
stratosphere mesosphere and when I'm

83
00:03:41,250 --> 00:03:37,330
talking about these conditions I mean

84
00:03:46,680 --> 00:03:41,260
temperature water content and incoming

85
00:03:48,900 --> 00:03:46,690
solar flux and so one of the things that

86
00:03:51,360 --> 00:03:48,910
the models have done to try and account

87
00:03:53,699 --> 00:03:51,370
for this is to implement this infrared

88
00:03:55,050 --> 00:03:53,709

visible fatalis asst of sulfuric acid

89
00:03:57,900 --> 00:03:55,060
that was some work done in our group o

90
00:04:00,420 --> 00:03:57,910
number of years ago and so in the case

91
00:04:01,800 --> 00:04:00,430
here what happens what's interesting is

92
00:04:03,930 --> 00:04:01,810
this is potala sis on the ground

93
00:04:07,140 --> 00:04:03,940
electronic state you're exciting a

94
00:04:09,330 --> 00:04:07,150
vibration this o.h stretch to the v

95
00:04:11,130 --> 00:04:09,340
equal for v equals 5 level and when that

96
00:04:13,020 --> 00:04:11,140
happens that hydrogen starts to hop

97
00:04:15,150 --> 00:04:13,030
across the molecule and can jump from

98
00:04:16,500 --> 00:04:15,160
one oxygen to another and in the case

99
00:04:19,349 --> 00:04:16,510
where it jumps to the oxygen that

100
00:04:22,200 --> 00:04:19,359
already has an o H you get photolysis

101
00:04:24,480 --> 00:04:22,210
and leading to so3 and water and when

102
00:04:25,950 --> 00:04:24,490
you're at the high altitude arm in the

103
00:04:28,290 --> 00:04:25,960
atmosphere where there's a lot of UV

104
00:04:30,890 --> 00:04:28,300
I'd available that s 03 then immediately

105
00:04:34,020 --> 00:04:30,900
photo Liza's to form s 02 so this is a

106
00:04:37,800 --> 00:04:34,030
photochemical source of so2 in the

107
00:04:39,540 --> 00:04:37,810
atmosphere however this doesn't even

108
00:04:41,969 --> 00:04:39,550
begin to account for the amount of so2

109
00:04:45,300 --> 00:04:41,979
that's observed in Venus's atmosphere

110
00:04:47,339 --> 00:04:45,310
and so the models do a couple of other

111
00:04:50,309 --> 00:04:47,349
things to then try and compensate and

112
00:04:52,770 --> 00:04:50,319
account for this that may or may not be

113
00:04:54,749 --> 00:04:52,780

physically accurate one of which is they

114
00:04:56,820 --> 00:04:54,759
include an inaccurate UV cross-section

115
00:04:58,920 --> 00:04:56,830
so they take the upper limits of

116
00:05:04,409 --> 00:04:58,930
measured cross sections from about 200

117
00:05:06,990 --> 00:05:04,419
to 300 and 20 nanometers and assume that

118
00:05:09,659 --> 00:05:07,000
all the light absorbed immediately leads

119
00:05:11,790 --> 00:05:09,669
to Fatah lysis although a lot of work

120
00:05:13,230 --> 00:05:11,800
that's been done has shown that this

121
00:05:15,810 --> 00:05:13,240
cross section actually is probably much

122
00:05:19,290 --> 00:05:15,820
smaller and is not actually leading to

123
00:05:20,909 --> 00:05:19,300
any sort of UV photolysis another thing

124
00:05:23,960 --> 00:05:20,919
they do is they include red light

125
00:05:26,670 --> 00:05:23,970
fotosis of the sulfuric acid monohydrate

126
00:05:29,640 --> 00:05:26,680
where the sulfuric acid molecule is

127
00:05:32,089 --> 00:05:29,650
complexed with a water molecule this

128
00:05:35,310 --> 00:05:32,099
does lower the barrier for this reaction

129
00:05:38,189 --> 00:05:35,320
however there is one problem with that

130
00:05:40,860 --> 00:05:38,199
and that a lot of work that's been done

131
00:05:42,450 --> 00:05:40,870
looking at this has shown that instead

132
00:05:44,820 --> 00:05:42,460
of leading to photolysis instead what

133
00:05:47,100 --> 00:05:44,830
happens as the energy goes into breaking

134
00:05:49,020 --> 00:05:47,110
these hydrogen bonds and leads to

135
00:05:51,689 --> 00:05:49,030
dissociation of the cluster rather than

136
00:05:53,879 --> 00:05:51,699
fatales as the sulfuric acid so neither

137
00:05:57,270 --> 00:05:53,889
of these things are likely to be

138
00:05:59,070 --> 00:05:57,280

actually happening in the atmosphere so

139
00:06:02,790 --> 00:05:59,080
this has led to us to ask the question

140
00:06:06,779 --> 00:06:02,800
of if we look at the entire system of

141
00:06:09,029 --> 00:06:06,789
so2 is there something else is there

142
00:06:11,370 --> 00:06:09,039
another reservoir some other molecule

143
00:06:14,700 --> 00:06:11,380
that could be photo lysing and leading

144
00:06:16,830 --> 00:06:14,710
to so2 in the atmosphere and so one

145
00:06:22,260 --> 00:06:16,840
thing that we started to look at is

146
00:06:25,680 --> 00:06:22,270
sulfurous acid h2so4 an h2 so4 and this

147
00:06:26,939 --> 00:06:25,690
is an interesting molecule it's tricky

148
00:06:28,999 --> 00:06:26,949
for a number of reasons it's never

149
00:06:31,439 --> 00:06:29,009
actually been observed in the gas phase

150
00:06:35,219 --> 00:06:31,449
and a couple of reasons for this is that

151
00:06:37,740 --> 00:06:35,229
h2s 03 is energetically uphill so so2

152
00:06:39,119 --> 00:06:37,750
plus water is energetically much more

153
00:06:42,629 --> 00:06:39,129
favorable to go down

154
00:06:45,239 --> 00:06:42,639
as well as you pay an entropic price for

155
00:06:48,989 --> 00:06:45,249
making h2s 03 as well as you go from two

156
00:06:51,239 --> 00:06:48,999
molecules to one and there's this large

157
00:06:55,649 --> 00:06:51,249
barrier to forming it so you need to get

158
00:06:57,239 --> 00:06:55,659
over the barrier and format and as you

159
00:06:58,949 --> 00:06:57,249
add more and more water you drop this

160
00:07:00,899 --> 00:06:58,959
barrier however when you drop that

161
00:07:05,639 --> 00:07:00,909
barrier it's much more likely for it to

162
00:07:08,100 --> 00:07:05,649
then fall apart and make so2 instead and

163
00:07:09,929 --> 00:07:08,110

so we've been looking for other ways to

164
00:07:11,459 --> 00:07:09,939
try and make this molecule and I've done

165
00:07:15,089 --> 00:07:11,469
some theoretical work with Jamie

166
00:07:16,769 --> 00:07:15,099
Donaldson and so you'll know I've kind

167
00:07:18,689 --> 00:07:16,779
of swapped directions here from s 0 to

168
00:07:21,179 --> 00:07:18,699
plus water to making the acid it's about

169
00:07:24,769 --> 00:07:21,189
five kcal per mole uphill you have this

170
00:07:27,809 --> 00:07:24,779
large barrier about 35 kcal per mole

171
00:07:30,869 --> 00:07:27,819
however there is this excited electronic

172
00:07:33,449 --> 00:07:30,879
state for so2 so it's this triplet state

173
00:07:35,459 --> 00:07:33,459
that you can excite to when you're there

174
00:07:37,649 --> 00:07:35,469
in a collision of water a relatively

175
00:07:41,429 --> 00:07:37,659
mild collision you can create this

176
00:07:44,279 --> 00:07:41,439
complex that then inner system crosses

177
00:07:45,600 --> 00:07:44,289
back to an excited singlet state which

178
00:07:47,339 --> 00:07:45,610
are just two different types of

179
00:07:49,139 --> 00:07:47,349
electronic states and then that singlet

180
00:07:51,809 --> 00:07:49,149
state can then proceed forward to make

181
00:07:53,909 --> 00:07:51,819
sulfurous acid and so this is a

182
00:07:57,600 --> 00:07:53,919
potentially new pathway to try and make

183
00:07:59,129 --> 00:07:57,610
this and so one thing I'd like to know

184
00:08:00,569 --> 00:07:59,139
is this triplet state is actually a

185
00:08:04,319 --> 00:08:00,579
forbidden transition you'll note that

186
00:08:05,969 --> 00:08:04,329
this is a spectrum x 500 so it's

187
00:08:08,059 --> 00:08:05,979
actually forbidden to go from the ground

188
00:08:10,859 --> 00:08:08,069

electronic state to that triplet state

189
00:08:14,040 --> 00:08:10,869
however there is this large singlet

190
00:08:17,939 --> 00:08:14,050
state absorption in so2 from about 250

191
00:08:20,939 --> 00:08:17,949
to 300 and 10 nanometers and there's

192
00:08:22,379 --> 00:08:20,949
been a lot of work done showing that you

193
00:08:24,299 --> 00:08:22,389
can excite this state and then that

194
00:08:27,089 --> 00:08:24,309
rapidly inner system crosses to the

195
00:08:30,540 --> 00:08:27,099
triplet state which can then go on to do

196
00:08:32,519 --> 00:08:30,550
reactions and so in my experiments we

197
00:08:35,040 --> 00:08:32,529
excite with a xenon arc lamp that's

198
00:08:36,569 --> 00:08:35,050
filtered so this filter shows that we

199
00:08:39,179 --> 00:08:36,579
cut off at about two hundred ninety five

200
00:08:41,129 --> 00:08:39,189
nanometers the reason why we do that is

201
00:08:44,389 --> 00:08:41,139
because we're trying to avoid exciting

202
00:08:47,189 --> 00:08:44,399
this state over here this is a

203
00:08:49,079 --> 00:08:47,199
photoactive state where so2 photo liza's

204
00:08:51,389 --> 00:08:49,089
to form sulfur monoxide and i'm excited

205
00:08:52,890 --> 00:08:51,399
oxygen atoms so we really wanted to

206
00:08:56,100 --> 00:08:52,900
avoid initiating

207
00:08:57,810 --> 00:08:56,110
any sort of chemistry with that so in

208
00:09:02,160 --> 00:08:57,820
our system we use this filter xenon

209
00:09:04,470 --> 00:09:02,170
light and then in at a right angle to

210
00:09:07,380 --> 00:09:04,480
that we have a green laser going through

211
00:09:09,600 --> 00:09:07,390
the system that we then detect and

212
00:09:11,580 --> 00:09:09,610
anytime you form any sort of aerosol

213
00:09:14,790 --> 00:09:11,590

that laser beam then gets scattered and

214
00:09:16,770 --> 00:09:14,800
you can measure a depletion in the laser

215
00:09:21,180 --> 00:09:16,780
intensity and show that you're actually

216
00:09:22,830 --> 00:09:21,190
making aerosol and so here you can

217
00:09:24,180 --> 00:09:22,840
actually see pictures of our experiment

218
00:09:26,970 --> 00:09:24,190
you can see that we have this green

219
00:09:28,380 --> 00:09:26,980
laser light going through this is with

220
00:09:29,970 --> 00:09:28,390
the lamp on when you have the lamp off

221
00:09:31,500 --> 00:09:29,980
you actually can't even see this laser

222
00:09:34,140 --> 00:09:31,510
beams you can see that there's a large

223
00:09:35,730 --> 00:09:34,150
amount of scattering of light and so

224
00:09:38,490 --> 00:09:35,740
then to give you something that's a

225
00:09:40,590 --> 00:09:38,500
little more quantitative if we have just

226
00:09:44,220 --> 00:09:40,600
water in the cell we turn on the lamp at

227
00:09:46,680 --> 00:09:44,230
time zero you get no depletion same

228
00:09:48,510 --> 00:09:46,690
thing if you have just so2 as soon as

229
00:09:50,700 --> 00:09:48,520
you have any sort of mixture you get a

230
00:09:52,470 --> 00:09:50,710
depletion and as we increase the ratio

231
00:09:55,610 --> 00:09:52,480
of so2 to water we get a larger

232
00:10:00,270 --> 00:09:55,620
depletion so we are forming aerosol

233
00:10:01,830 --> 00:10:00,280
through some sort of acid formation so

234
00:10:03,660 --> 00:10:01,840
one question we wanted to really make

235
00:10:05,160 --> 00:10:03,670
sure of is this oh h chemistry this

236
00:10:07,080 --> 00:10:05,170
traditional o-h chemistry in our

237
00:10:09,000 --> 00:10:07,090
atmosphere we want to make sure that

238
00:10:10,590 --> 00:10:09,010

wasn't happening so a common thing in

239
00:10:13,830 --> 00:10:10,600
atmospheric experiments is to use

240
00:10:15,330 --> 00:10:13,840
cyclohexane as an o H scavenger to react

241
00:10:18,320 --> 00:10:15,340
with all of the o H that's potentially

242
00:10:20,760 --> 00:10:18,330
there and remove it from the system

243
00:10:23,040 --> 00:10:20,770
there's just one problem with this it

244
00:10:24,960 --> 00:10:23,050
turns out the so2 if you have

245
00:10:26,370 --> 00:10:24,970
cyclohexane as soon as you excite and

246
00:10:29,340 --> 00:10:26,380
you end up in that triplet state it

247
00:10:31,470 --> 00:10:29,350
rapidly reacts with cyclohexane to form

248
00:10:33,780 --> 00:10:31,480
aerosol even faster than you do with

249
00:10:36,570 --> 00:10:33,790
water so it fills the cell with this

250
00:10:38,580 --> 00:10:36,580
iridescent cloud and there's not a lot

251
00:10:40,650 --> 00:10:38,590
that we can do about that we did do

252
00:10:42,420 --> 00:10:40,660
experiments with cyclohexane and just

253
00:10:44,220 --> 00:10:42,430
water to make sure that there was no

254
00:10:47,820 --> 00:10:44,230
aerosol formation and we don't see any

255
00:10:49,710 --> 00:10:47,830
aerosol formation there so we relatively

256
00:10:52,080 --> 00:10:49,720
sure that there's no o H chemistry going

257
00:10:56,070 --> 00:10:52,090
on however we can't include this with

258
00:10:57,840 --> 00:10:56,080
the so2 in the system and so instead a

259
00:11:00,780 --> 00:10:57,850
turn to a kinetics box model so a

260
00:11:02,280 --> 00:11:00,790
relatively simple kinetics box model but

261
00:11:04,200 --> 00:11:02,290
one thing to point out is that it is

262
00:11:05,689 --> 00:11:04,210
possible through s 0 to s 0 to

263
00:11:08,319 --> 00:11:05,699

collisions

264
00:11:14,119 --> 00:11:08,329
we can make so3 that would go on to form

265
00:11:18,789 --> 00:11:14,129
sulfuric acid and so we look at this so3

266
00:11:21,049 --> 00:11:18,799
collisions using the side bottom at all

267
00:11:23,449 --> 00:11:21,059
collisional deactivation of this triplet

268
00:11:25,549 --> 00:11:23,459
state we assume that some fraction this

269
00:11:28,729 --> 00:11:25,559
branching ratio leads to a formation of

270
00:11:30,379 --> 00:11:28,739
acid and so if we assume that the

271
00:11:32,449 --> 00:11:30,389
branching ratio is a hundred percent we

272
00:11:36,139 --> 00:11:32,459
can see that this blue line is sulfurous

273
00:11:40,009 --> 00:11:36,149
acid in either case far out competes the

274
00:11:42,289 --> 00:11:40,019
formation of sulfuric acid and in the

275
00:11:44,419 --> 00:11:42,299
lower concentration so2 where you

276
00:11:45,949 --> 00:11:44,429
decrease those s 0 to s are two

277
00:11:48,379 --> 00:11:45,959
interactions we actually lead to an even

278
00:11:50,720 --> 00:11:48,389
larger increase and so if we instead

279
00:11:53,389 --> 00:11:50,730
look at the ratio of sulfurous to

280
00:11:54,949 --> 00:11:53,399
sulfuric acid formation you'll note that

281
00:11:58,009 --> 00:11:54,959
you do not need to have a branching

282
00:11:59,989 --> 00:11:58,019
ratio of a hundred percent if we go to

283
00:12:01,189 --> 00:11:59,999
these much lower concentrations of so2

284
00:12:04,340 --> 00:12:01,199
where I've now done some more

285
00:12:05,989 --> 00:12:04,350
experiments of that you can even have a

286
00:12:07,819 --> 00:12:05,999
branching ratio of one or two percent

287
00:12:11,809 --> 00:12:07,829
and still outcompete that formation of

288
00:12:13,879 --> 00:12:11,819

sulfuric acid and so with that I just

289
00:12:15,470 --> 00:12:13,889
like to acknowledge my group and sources

290
00:12:16,639 --> 00:12:15,480
of funding and thank you guys for your

291
00:12:26,889 --> 00:12:16,649
time and I'd be happy to take some

292
00:12:31,759 --> 00:12:29,720
can you resolve differences in stable

293
00:12:35,239 --> 00:12:31,769
isotopes of sulfur species

294
00:12:38,179 --> 00:12:35,249
spectroscopically um so with our system

295
00:12:40,579 --> 00:12:38,189
we cannot I don't have the ability to

296
00:12:44,239 --> 00:12:40,589
look at different isotopes however I'm

297
00:12:48,410 --> 00:12:44,249
definitely interested in doing some mass

298
00:12:49,910 --> 00:12:48,420
spec experiments where depending on the

299
00:12:51,499 --> 00:12:49,920
mass spectrometer we might be able to

300
00:12:54,379 --> 00:12:51,509
actually look at that this is definitely

301
00:12:56,809 --> 00:12:54,389
that triplet state that inner conversion

302
00:12:58,160 --> 00:12:56,819
from the singlet to triplet state does

303
00:13:00,319 --> 00:12:58,170
depend on the mass of the sulfur

304
00:13:02,210 --> 00:13:00,329
isotopes and so it will lead to a sulfur

305
00:13:04,249 --> 00:13:02,220
mass independent pretty experimental

306
00:13:07,519 --> 00:13:04,259
work but for the I guess the

307
00:13:09,049 --> 00:13:07,529
observations that you're doing um so the

308
00:13:11,900 --> 00:13:09,059
observations were done with Venus

309
00:13:21,559 --> 00:13:11,910
Express I know they definitely can't

310
00:13:22,999 --> 00:13:21,569
unfortunately yeah other questions all