METEORITE OUTGASSING EXPERIMENTS TO INFORM CHEMICAL ABUNDANCES OF SUPER EARTH ATMOSPHERES

MAGGIE THOMPSON

1
00:00:09,379 --> 00:00:07,610
[Music]

2
00:00:11,600 --> 00:00:09,389
because hi everyone my name is Maggie

3
00:00:14,180 --> 00:00:11,610
Thompson I am a graduate student at UC

4
00:00:16,519 --> 00:00:14,190
Santa Cruz it's a real honor to be here

5
00:00:18,560 --> 00:00:16,529
today to get to tell you all about the

6
00:00:20,120 --> 00:00:18,570
meteorite outgassing experiments that I

7
00:00:22,429 --> 00:00:20,130
have been doing over the last year or so

8
00:00:24,710 --> 00:00:22,439
in the lab and how these can inform

9
00:00:26,509 --> 00:00:24,720
chemical abundances of super earth and

10
00:00:29,750 --> 00:00:26,519
other lower mass rocky planet

11
00:00:31,580 --> 00:00:29,760
atmospheres of course I'd like to take a

12
00:00:33,470 --> 00:00:31,590
moment to thank my collaborators it's

13
00:00:35,680 --> 00:00:33,480

not intimidating at all to go right

14
00:00:38,299 --> 00:00:35,690
after my adviser Jonathan Fortney and

15
00:00:40,580 --> 00:00:38,309
Miriam Telus though that UC Santa Cruz

16
00:00:41,930 --> 00:00:40,590
and others including Laura Schaeffer who

17
00:00:44,180 --> 00:00:41,940
we will hear from later this afternoon

18
00:00:47,660 --> 00:00:44,190
and others who helped make this work

19
00:00:49,130 --> 00:00:47,670
possible to start here's a brief road

20
00:00:50,720 --> 00:00:49,140
map of where we're going for the next

21
00:00:52,310 --> 00:00:50,730
few minutes I'm going to start by

22
00:00:54,619 --> 00:00:52,320
discussing the different possible

23
00:00:56,720 --> 00:00:54,629
formation mechanisms for super earth and

24
00:00:58,459 --> 00:00:56,730
other lower mass planet atmospheres and

25
00:01:00,830 --> 00:00:58,469
also talk about some of the assumptions

26
00:01:02,510 --> 00:01:00,840
that we typically put in our models for

27
00:01:05,299 --> 00:01:02,520
what these atmospheres are likely made

28
00:01:07,670 --> 00:01:05,309
out of then I'll motivate how meteorites

29
00:01:10,850 --> 00:01:07,680
can help inform the initial super earth

30
00:01:12,350 --> 00:01:10,860
atmospheres that we expect and therefore

31
00:01:14,840 --> 00:01:12,360
motivating why we're doing experiments

32
00:01:16,160 --> 00:01:14,850
in the lab and explain our setup then

33
00:01:20,270 --> 00:01:16,170
I'll discuss some of our current

34
00:01:22,520 --> 00:01:20,280
experimental results and future work so

35
00:01:23,330 --> 00:01:22,530
to start how do super Earths obtain

36
00:01:24,980 --> 00:01:23,340
their atmospheres

37
00:01:26,960 --> 00:01:24,990
I think clearly this is very much an

38
00:01:28,730 --> 00:01:26,970

unanswered question and very important

39
00:01:30,050 --> 00:01:28,740
within the field and it's likely that

40
00:01:32,719 --> 00:01:30,060
super earths are going to have a wide

41
00:01:34,490 --> 00:01:32,729
diverse range of atmospheres from what

42
00:01:36,260 --> 00:01:34,500
we've been talking about earlier this

43
00:01:37,940 --> 00:01:36,270
morning hydrogen rich primary

44
00:01:38,810 --> 00:01:37,950
atmospheres that accrete from the

45
00:01:40,760 --> 00:01:38,820
stellar nebula

46
00:01:43,249 --> 00:01:40,770
to potentially terrestrial like

47
00:01:45,139 --> 00:01:43,259
secondary atmospheres that instead form

48
00:01:47,569 --> 00:01:45,149
via al gassing look here I just have

49
00:01:49,999 --> 00:01:47,579
some two little schematics yes that I'm

50
00:01:52,310 --> 00:01:50,009
showing on the top and on the bottom so

51
00:01:54,499 --> 00:01:52,320
primary is in the red and then secondary

52
00:01:56,870 --> 00:01:54,509
atmospheres is in the blue and so it's

53
00:01:59,690 --> 00:01:56,880
likely that a subset of super Earths

54
00:02:02,209 --> 00:01:59,700
and other low mass exoplanets will

55
00:02:04,010 --> 00:02:02,219
likely not be able to retain significant

56
00:02:05,270 --> 00:02:04,020
primary atmospheres of course as we

57
00:02:07,429 --> 00:02:05,280
talked about with atmospheric escape

58
00:02:09,830 --> 00:02:07,439
this morning this is super complicated

59
00:02:11,330 --> 00:02:09,840
but it's so likely that some of them

60
00:02:13,120 --> 00:02:11,340
won't be able to hold on to them for

61
00:02:14,890 --> 00:02:13,130
very long and so instead

62
00:02:17,230 --> 00:02:14,900
secondary atmospheres that form via out

63
00:02:18,880 --> 00:02:17,240

gassing are going to be important so for

64
00:02:21,460 --> 00:02:18,890
the remainder of my talk I'm going to be

65
00:02:23,280 --> 00:02:21,470
focusing on these secondary Alka Singh

66
00:02:26,320 --> 00:02:23,290
atmospheres

67
00:02:28,450 --> 00:02:26,330
okay so I think it's been made very

68
00:02:30,970 --> 00:02:28,460
clear throughout this EXO climb so we're

69
00:02:32,920 --> 00:02:30,980
at this very exciting next phase in

70
00:02:35,200 --> 00:02:32,930
exoplanet science where we're pushing to

71
00:02:37,990 --> 00:02:35,210
being able to characterize the physics

72
00:02:40,360 --> 00:02:38,000
and chemistry of lower mass super earth

73
00:02:42,640 --> 00:02:40,370
atmospheres and then one day even

74
00:02:45,310 --> 00:02:42,650
pushing to rocky planet atmospheres and

75
00:02:47,050 --> 00:02:45,320
as Jonathan talked a little bit about we

76
00:02:48,730 --> 00:02:47,060
currently don't have a real first

77
00:02:51,370 --> 00:02:48,740
principles understanding of how to

78
00:02:53,440 --> 00:02:51,380
connect a planet's interior or its bulk

79
00:02:54,640 --> 00:02:53,450
composition to its atmospheric

80
00:02:57,700 --> 00:02:54,650
properties I think this is especially

81
00:03:00,100 --> 00:02:57,710
true for these lower mass planets and so

82
00:03:02,410 --> 00:03:00,110
until we have observational constraints

83
00:03:04,630 --> 00:03:02,420
that become available that we expect to

84
00:03:06,580 --> 00:03:04,640
have in the coming years we have to make

85
00:03:08,410 --> 00:03:06,590
assumptions about what these planets are

86
00:03:10,210 --> 00:03:08,420
made of and we have to resort to models

87
00:03:12,430 --> 00:03:10,220
so here I just want to briefly review

88
00:03:14,200 --> 00:03:12,440

some of the common assumptions that we

89
00:03:16,420 --> 00:03:14,210
make in terms of what these atmospheres

90
00:03:18,580 --> 00:03:16,430
are composed of looking at solar

91
00:03:21,010 --> 00:03:18,590
abundances or some multiple of solar

92
00:03:23,350 --> 00:03:21,020
abundances or perhaps giving planet

93
00:03:25,750 --> 00:03:23,360
solar system planet abundances so get a

94
00:03:27,940 --> 00:03:25,760
take Earth's atmospheric composition and

95
00:03:29,560 --> 00:03:27,950
put that into our models or also ad hoc

96
00:03:31,810 --> 00:03:29,570
abundances so sometimes we'll have a

97
00:03:33,910 --> 00:03:31,820
carbon dioxide dominated atmosphere

98
00:03:37,900 --> 00:03:33,920
whereas team dominated water atmosphere

99
00:03:40,090 --> 00:03:37,910
or some ad hoc combination so with that

100
00:03:41,620 --> 00:03:40,100
in mind I'm now gonna motivate why we

101
00:03:44,050 --> 00:03:41,630
would want to measure the out gas

102
00:03:47,199 --> 00:03:44,060
volatiles from meteorites and how this

103
00:03:48,970 --> 00:03:47,209
can help inform these secondary super or

104
00:03:51,820 --> 00:03:48,980
lower mass planet atmospheric

105
00:03:54,220 --> 00:03:51,830
compositions so we believe in general

106
00:03:55,660 --> 00:03:54,230
that planets in our solar system formed

107
00:03:57,970 --> 00:03:55,670
out of material that's approximately

108
00:03:59,710 --> 00:03:57,980
analogous to meteorites I'll talk a

109
00:04:02,110 --> 00:03:59,720
little bit more about that statement in

110
00:04:04,150 --> 00:04:02,120
the coming slides and as we just

111
00:04:06,640 --> 00:04:04,160
discussed some super earth atmospheres

112
00:04:09,160 --> 00:04:06,650
or lower mass rocky planets are unlikely

113
00:04:10,210 --> 00:04:09,170

or likely to form their atmospheres

114
00:04:12,730 --> 00:04:10,220
through outgassing

115
00:04:15,370 --> 00:04:12,740
during accretion and so therefore if we

116
00:04:18,099 --> 00:04:15,380
measure the AB gassing composition from

117
00:04:20,740 --> 00:04:18,109
meteorites this can help inform the

118
00:04:23,860 --> 00:04:20,750
initial outlast atmosphere compositions

119
00:04:24,970 --> 00:04:23,870
of soup earth now when I have this this

120
00:04:26,620 --> 00:04:24,980
little

121
00:04:28,870 --> 00:04:26,630
I'm addict here I want to point out that

122
00:04:30,700 --> 00:04:28,880
I'm not making a one-to-one comparison

123
00:04:32,590 --> 00:04:30,710
here I'm not going to say that one

124
00:04:34,540 --> 00:04:32,600
particular meteorite this little rock

125
00:04:37,390 --> 00:04:34,550
that we were lucky enough to have land

126
00:04:39,220 --> 00:04:37,400
on earth it's going to be exactly what a

127
00:04:40,690 --> 00:04:39,230
planet is going to be made out of but

128
00:04:44,590 --> 00:04:40,700
these are the building blocks and so

129
00:04:46,000 --> 00:04:44,600
this is at least a place to start so

130
00:04:48,160 --> 00:04:46,010
when I say meteorites what type of

131
00:04:50,530 --> 00:04:48,170
meteorites am I talking about for those

132
00:04:52,030 --> 00:04:50,540
that are not as familiar with

133
00:04:54,400 --> 00:04:52,040
cosmochemistry I just want to briefly

134
00:04:56,050 --> 00:04:54,410
review that there are two main types of

135
00:04:58,030 --> 00:04:56,060
meteorites there are those that went

136
00:05:00,220 --> 00:04:58,040
through a significant amount of heating

137
00:05:02,470 --> 00:05:00,230
and differentiated and melted and that

138
00:05:04,900 --> 00:05:02,480

those that didn't so for the work that

139
00:05:06,550 --> 00:05:04,910
I'm doing I'm focusing on what a type of

140
00:05:08,410 --> 00:05:06,560
meteorites that we call Kandra if these

141
00:05:10,390 --> 00:05:08,420
are the ones that did not experience a

142
00:05:12,210 --> 00:05:10,400
significant amount of heating they are

143
00:05:15,130 --> 00:05:12,220
believed to be a record of the original

144
00:05:17,530 --> 00:05:15,140
components that formed planetesimals and

145
00:05:19,420 --> 00:05:17,540
planets in our solar system and amongst

146
00:05:22,060 --> 00:05:19,430
chondrites there are other types as well

147
00:05:24,130 --> 00:05:22,070
I'm focusing on two types the ordinary

148
00:05:25,840 --> 00:05:24,140
chondrite has the name success these are

149
00:05:28,330 --> 00:05:25,850
the most common type of chondrite that

150
00:05:30,820 --> 00:05:28,340
we find on earth they contain oxidized

151
00:05:32,260 --> 00:05:30,830
and volatile elements and they may have

152
00:05:34,090 --> 00:05:32,270
formed in the inner asteroid belt

153
00:05:35,310 --> 00:05:34,100
although this is certainly an active

154
00:05:38,170 --> 00:05:35,320
area of research within the

155
00:05:40,150 --> 00:05:38,180
cosmochemistry community then the second

156
00:05:42,130 --> 00:05:40,160
type are carbonaceous chondrite these

157
00:05:44,140 --> 00:05:42,140
have up to 20 percent water they have

158
00:05:46,480 --> 00:05:44,150
the highest proportion of volatiles out

159
00:05:47,680 --> 00:05:46,490
of the other chondrite groups and they

160
00:05:51,040 --> 00:05:47,690
are believed to have originated from

161
00:05:52,930 --> 00:05:51,050
further beyond the asteroid belt again

162
00:05:55,900 --> 00:05:52,940
still something that people are working

163
00:05:58,330 --> 00:05:55,910

on studying that distribution so why

164
00:06:00,190 --> 00:05:58,340
exactly are chondritic meteorites the

165
00:06:03,130 --> 00:06:00,200
most applicable to super earth

166
00:06:05,020 --> 00:06:03,140
atmospheric studies so it turns out that

167
00:06:06,820 --> 00:06:05,030
the volatiles the really heavily

168
00:06:10,510 --> 00:06:06,830
volatile elements in the earth like

169
00:06:12,940 --> 00:06:10,520
hydrogen nitrogen oxygen are believed to

170
00:06:15,670 --> 00:06:12,950
have originated from the same reservoir

171
00:06:17,590 --> 00:06:15,680
that sourced the parent bodies of the

172
00:06:19,720 --> 00:06:17,600
chondritic meteorites and so this is

173
00:06:21,940 --> 00:06:19,730
being evidenced here in this plot from

174
00:06:24,100 --> 00:06:21,950
marty 2012 where they're plotting the

175
00:06:27,190 --> 00:06:24,110
isotopic composition of hydrogen

176
00:06:29,680 --> 00:06:27,200
expressed by the b2h ratio and then the

177
00:06:31,780 --> 00:06:29,690
isotopic composition of nitrogen and you

178
00:06:33,940 --> 00:06:31,790
can see in this like dark pink circle

179
00:06:35,740 --> 00:06:33,950
that the Earth's surface layers so this

180
00:06:37,430 --> 00:06:35,750
is including Earth's oceans and the

181
00:06:39,710 --> 00:06:37,440
atmosphere a very

182
00:06:42,410 --> 00:06:39,720
similar value to if you were to average

183
00:06:43,100 --> 00:06:42,420
the ordinary and carbonaceous chondrites

184
00:06:46,540 --> 00:06:43,110
together

185
00:06:49,700 --> 00:06:46,550
so therefore in general the average

186
00:06:51,350 --> 00:06:49,710
volatile abundances from ordinary and

187
00:06:53,450 --> 00:06:51,360
carbonaceous chondrites are pretty

188
00:06:55,880 --> 00:06:53,460

similar to what we see in Earth's

189
00:07:00,410 --> 00:06:55,890
atmosphere and surface layers so this is

190
00:07:02,420 --> 00:07:00,420
a good place to start okay so people

191
00:07:04,550 --> 00:07:02,430
have been interested in meteorite

192
00:07:06,590 --> 00:07:04,560
outgassing and its implications for

193
00:07:08,750 --> 00:07:06,600
planet atmospheres before particularly

194
00:07:10,400 --> 00:07:08,760
from a theoretical point of view so

195
00:07:12,650 --> 00:07:10,410
Laura Schaeffer and Bruce Begley in a

196
00:07:16,220 --> 00:07:12,660
series of papers modeled the thermal

197
00:07:18,500 --> 00:07:16,230
outgassing from various chondrites using

198
00:07:20,060 --> 00:07:18,510
chemical equilibrium calculations and so

199
00:07:21,830 --> 00:07:20,070
here this is some of the results from

200
00:07:24,740 --> 00:07:21,840
their work where they are showing the

201
00:07:26,240 --> 00:07:24,750
mole the mole fraction on a log scale so

202
00:07:28,850 --> 00:07:26,250
you can think of that as abundance as a

203
00:07:31,070 --> 00:07:28,860
function of temperature and pressure for

204
00:07:33,020 --> 00:07:31,080
a variety of chondrites and so you're

205
00:07:34,640 --> 00:07:33,030
seeing here the different gases that

206
00:07:36,770 --> 00:07:34,650
come off through doing these

207
00:07:39,440 --> 00:07:36,780
calculations and they've applied these

208
00:07:41,570 --> 00:07:39,450
calculated outgassing abundances to

209
00:07:43,700 --> 00:07:41,580
initial terrestrial planet atmospheres

210
00:07:46,010 --> 00:07:43,710
for instance looking at early Earth and

211
00:07:48,110 --> 00:07:46,020
what the implication may be for that but

212
00:07:50,210 --> 00:07:48,120
unfortunately there are no experimental

213
00:07:52,340 --> 00:07:50,220

data to really constrain these

214
00:07:55,940 --> 00:07:52,350
theoretical calculations and so that's

215
00:07:58,850 --> 00:07:55,950
where we come in so this is a schematic

216
00:08:01,280 --> 00:07:58,860
of the meteorite heating experiments

217
00:08:04,400 --> 00:08:01,290
that we're doing in the lab this lab is

218
00:08:06,950 --> 00:08:04,410
a bit bigger than this table but but not

219
00:08:09,350 --> 00:08:06,960
by a whole much and so what we have is a

220
00:08:12,830 --> 00:08:09,360
furnace that can go up to 1,200 degrees

221
00:08:14,810 --> 00:08:12,840
Celsius or 1500 Kelvin we place our

222
00:08:16,880 --> 00:08:14,820
meteorite sample into this little

223
00:08:18,560 --> 00:08:16,890
crucible here that little yellow that

224
00:08:22,130 --> 00:08:18,570
little yellow block and then we heat up

225
00:08:23,990 --> 00:08:22,140
our sample and we measure it using a

226
00:08:26,300 --> 00:08:24,000
type of mass spectrometer it's called a

227
00:08:28,880 --> 00:08:26,310
residual gas analyzer so this is a

228
00:08:31,400 --> 00:08:28,890
machine that's often used in physics

229
00:08:33,680 --> 00:08:31,410
labs or various other labs to measure

230
00:08:36,170 --> 00:08:33,690
and to check your vacuum environment or

231
00:08:38,899 --> 00:08:36,180
to measure trace amounts of gases and so

232
00:08:40,130 --> 00:08:38,909
it's particularly sensitive to all the

233
00:08:42,560 --> 00:08:40,140
different gases that are coming off of

234
00:08:44,300 --> 00:08:42,570
your sample and so what it measures is

235
00:08:46,370 --> 00:08:44,310
the partial pressure of different

236
00:08:48,890 --> 00:08:46,380
species as a function of the temperature

237
00:08:50,660 --> 00:08:48,900
which you're heating your samples to and

238
00:08:51,290 --> 00:08:50,670

so for each of our samples we powder

239
00:08:53,660 --> 00:08:51,300
them

240
00:08:56,060 --> 00:08:53,670
and so that means literally crushing a

241
00:08:57,740 --> 00:08:56,070
meteorite sample with an agate mortar

242
00:08:59,210 --> 00:08:57,750
and pestle in the lab which is very

243
00:09:01,610 --> 00:08:59,220
exciting for me the first time I got to

244
00:09:04,160 --> 00:09:01,620
do that and I'm only using 3 milligrams

245
00:09:06,290 --> 00:09:04,170
per experiment that I run so I'm not

246
00:09:08,780 --> 00:09:06,300
wasting too many of these very precious

247
00:09:11,030 --> 00:09:08,790
materials that we have on earth and I'm

248
00:09:13,490 --> 00:09:11,040
doing all of these experiments at very

249
00:09:15,920 --> 00:09:13,500
low pressures you can see here around 10

250
00:09:18,350 --> 00:09:15,930
to the minus 8 bars this is because we

251
00:09:20,720 --> 00:09:18,360
don't want any contamination that is due

252
00:09:22,790 --> 00:09:20,730
to just the air in the room and so we're

253
00:09:25,610 --> 00:09:22,800
trying to be sure that we minimize that

254
00:09:27,710 --> 00:09:25,620
contamination and we are also doing it

255
00:09:30,500 --> 00:09:27,720
so that our residual gas analyzer can

256
00:09:32,180 --> 00:09:30,510
operate properly this is just a brief

257
00:09:34,760 --> 00:09:32,190
overview of the type of experiments we

258
00:09:37,400 --> 00:09:34,770
do we tend to first heat up our samples

259
00:09:39,590 --> 00:09:37,410
to 200 degrees Celsius to get rid of any

260
00:09:42,440 --> 00:09:39,600
adsorbed water so these meteorites have

261
00:09:45,080 --> 00:09:42,450
been sitting in earth for quite a number

262
00:09:46,760 --> 00:09:45,090
of years and so they tend to gain water

263
00:09:48,770 --> 00:09:46,770

just from Earth's atmosphere that's not

264
00:09:50,540 --> 00:09:48,780
intrinsic to the sample so we want to

265
00:09:52,520 --> 00:09:50,550
try to get as much of that off as we can

266
00:09:55,490 --> 00:09:52,530
and then we heat up to 1,200 degrees

267
00:09:59,660 --> 00:09:55,500
Celsius over five hours and measure the

268
00:10:01,280 --> 00:09:59,670
outgassing volatiles that come up so

269
00:10:04,340 --> 00:10:01,290
here's an example of some of our results

270
00:10:06,500 --> 00:10:04,350
so this is data that we took for a

271
00:10:08,810 --> 00:10:06,510
really interesting carbonaceous

272
00:10:12,020 --> 00:10:08,820
chondrite it's called aguas Arcas it was

273
00:10:14,300 --> 00:10:12,030
a fall in Costa Rica this year so if

274
00:10:16,970 --> 00:10:14,310
anybody read in the news it fell on to a

275
00:10:18,380 --> 00:10:16,980
dog house and the dog is fine but the

276
00:10:21,170 --> 00:10:18,390
dog was named rocky which is very

277
00:10:22,490 --> 00:10:21,180
appropriate in my opinion and so this is

278
00:10:24,530 --> 00:10:22,500
showing you the partial pressure of

279
00:10:25,700 --> 00:10:24,540
different gases as a function of

280
00:10:28,070 --> 00:10:25,710
temperature that we're heating our

281
00:10:29,900 --> 00:10:28,080
samples to and so you can see though

282
00:10:32,510 --> 00:10:29,910
maybe something that's puzzling you is

283
00:10:34,550 --> 00:10:32,520
that for some of these gases we are

284
00:10:36,350 --> 00:10:34,560
measuring potentially two different

285
00:10:38,390 --> 00:10:36,360
species and so the reason for this is

286
00:10:41,270 --> 00:10:38,400
that the mass spectrometer is measuring

287
00:10:42,890 --> 00:10:41,280
things by their mass number and so if

288
00:10:45,080 --> 00:10:42,900

you look at the periodic table certain

289
00:10:48,020 --> 00:10:45,090
species overlap so for instance carbon

290
00:10:49,790 --> 00:10:48,030
monoxide and nitrogen have the same mass

291
00:10:51,530 --> 00:10:49,800
number which makes it a little bit

292
00:10:53,240 --> 00:10:51,540
trickier in our analysis to be sure that

293
00:10:55,160 --> 00:10:53,250
we can disentangle between these two

294
00:10:56,360 --> 00:10:55,170
that's part of the thing that we are

295
00:10:59,780 --> 00:10:56,370
working on and trying to really

296
00:11:02,600 --> 00:10:59,790
understand this data so we can now

297
00:11:04,700 --> 00:11:02,610
compare our experimental results to

298
00:11:07,010 --> 00:11:04,710
theoretical studies and so here

299
00:11:09,170 --> 00:11:07,020
showing you this is now mole fraction as

300
00:11:11,030 --> 00:11:09,180
a function of temperature these are

301
00:11:12,980 --> 00:11:11,040
theoretical chemical equilibrium

302
00:11:15,200 --> 00:11:12,990
calculations courtesy of Laura Shafer

303
00:11:16,970 --> 00:11:15,210
that were conducted for the same

304
00:11:19,010 --> 00:11:16,980
meteorite sample that we measured in the

305
00:11:21,020 --> 00:11:19,020
lab under these same low pressure

306
00:11:22,820 --> 00:11:21,030
conditions if you'll notice there's a

307
00:11:25,370 --> 00:11:22,830
lot of different things that come off

308
00:11:27,350 --> 00:11:25,380
I'm bolding the ones that we have

309
00:11:28,880 --> 00:11:27,360
measured in our experiment we're limited

310
00:11:31,160 --> 00:11:28,890
with our mass spectrometer we can't

311
00:11:34,130 --> 00:11:31,170
measure infinim infinite number of

312
00:11:35,510 --> 00:11:34,140
species at a time so the bold ones are

313
00:11:37,760 --> 00:11:35,520

the ones that match the stuff that we've

314
00:11:40,070 --> 00:11:37,770
measured and so then here are our

315
00:11:42,020 --> 00:11:40,080
experimental results and so I'm just

316
00:11:44,540 --> 00:11:42,030
gonna briefly touch on some similarities

317
00:11:46,910 --> 00:11:44,550
and differences between these two the

318
00:11:49,280 --> 00:11:46,920
main similarity that you'll notice is

319
00:11:51,380 --> 00:11:49,290
that water is the dominant species that

320
00:11:53,930 --> 00:11:51,390
is outgassed almost over almost all

321
00:11:56,270 --> 00:11:53,940
temperature ranges not all you'll also

322
00:11:59,990 --> 00:11:56,280
notice that our carbon monoxide nitrogen

323
00:12:02,620 --> 00:12:00,000
trend is fairly similar in both cases

324
00:12:05,900 --> 00:12:02,630
one interesting result is hydrogen

325
00:12:07,360 --> 00:12:05,910
sulfide has a similar outgassing trend

326
00:12:10,430 --> 00:12:07,370
but ours peaks at a higher temperature

327
00:12:12,730 --> 00:12:10,440
and this could be due to the phase that

328
00:12:15,230 --> 00:12:12,740
sulfur is locked in in these meteorite

329
00:12:17,540 --> 00:12:15,240
minerals and having to undergo a phase

330
00:12:18,950 --> 00:12:17,550
change in order to out gas so there's a

331
00:12:20,660 --> 00:12:18,960
lot of different things that we have to

332
00:12:23,180 --> 00:12:20,670
unpack here but this is just an example

333
00:12:25,250 --> 00:12:23,190
of some preliminary results of course

334
00:12:27,350 --> 00:12:25,260
you'll notice some differences one of

335
00:12:30,650 --> 00:12:27,360
the main ones being that hydrogen gas is

336
00:12:32,900 --> 00:12:30,660
the main it's the second most abundant

337
00:12:34,880 --> 00:12:32,910
species that comes off you'll notice I

338
00:12:37,040 --> 00:12:34,890

don't have that here we did measure

339
00:12:39,200 --> 00:12:37,050
hydrogen gas but we're not exactly

340
00:12:40,910 --> 00:12:39,210
confident that the hydrogen gas that

341
00:12:43,820 --> 00:12:40,920
we're measuring is actually coming from

342
00:12:45,530 --> 00:12:43,830
hydrogen gas and not an fragment of

343
00:12:48,290 --> 00:12:45,540
water given the way our mass

344
00:12:50,090 --> 00:12:48,300
spectrometer works it's ionizing the gas

345
00:12:52,580 --> 00:12:50,100
does that come in and so it might be an

346
00:12:55,220 --> 00:12:52,590
ion fragment coming off of water so this

347
00:12:56,930 --> 00:12:55,230
is a lot of just exciting things that we

348
00:13:00,170 --> 00:12:56,940
have to keep working on the main

349
00:13:01,790 --> 00:13:00,180
conclusion being that our results are

350
00:13:03,980 --> 00:13:01,800
showing you that in the lab we're not

351
00:13:06,560 --> 00:13:03,990
reaching chemical equilibrium and I

352
00:13:08,210 --> 00:13:06,570
think that that is to be expected and

353
00:13:11,450 --> 00:13:08,220
there's kinetics effects that we have to

354
00:13:13,280 --> 00:13:11,460
take into account so just to close up

355
00:13:15,560 --> 00:13:13,290
just want to briefly discuss some of the

356
00:13:17,390 --> 00:13:15,570
future work I plan to do this includes

357
00:13:17,980 --> 00:13:17,400
performing additional meteorite heating

358
00:13:19,870 --> 00:13:17,990
Experion

359
00:13:21,760 --> 00:13:19,880
focusing on the ordinary chondrite i

360
00:13:24,640 --> 00:13:21,770
also want to modify our experimental

361
00:13:26,500 --> 00:13:24,650
procedure to get rid of the amount of

362
00:13:28,780 --> 00:13:26,510
stuff that we are having the water that

363
00:13:30,490 --> 00:13:28,790

gets absorbed at 200 degrees so I want

364
00:13:32,200 --> 00:13:30,500
to hold it there for longer and also

365
00:13:34,510 --> 00:13:32,210
measure some of these other gases like

366
00:13:36,280 --> 00:13:34,520
sulfur dioxide and water and things that

367
00:13:38,230 --> 00:13:36,290
are predicted to come out in chemical

368
00:13:40,840 --> 00:13:38,240
equilibrium calculations and then

369
00:13:42,220 --> 00:13:40,850
ultimately we want to place the results

370
00:13:44,800 --> 00:13:42,230
from these experiments in the larger

371
00:13:46,720 --> 00:13:44,810
context of our exoplanet models so we

372
00:13:48,820 --> 00:13:46,730
want to simulate atmospheres that have a

373
00:13:50,860 --> 00:13:48,830
proper surface boundary condition that

374
00:13:53,380 --> 00:13:50,870
have a prescription to treat outgassing

375
00:13:56,290 --> 00:13:53,390
and secondary atmospheres and have our

376
00:13:57,730 --> 00:13:56,300
abundances informed by these results so

377
00:14:00,130 --> 00:13:57,740
I'll just close with my two take-home

378
00:14:02,140 --> 00:14:00,140
points measuring the out gas volatiles

379
00:14:04,150 --> 00:14:02,150
from a variety of chondritic meteorites

380
00:14:05,650 --> 00:14:04,160
samples and provide experimental

381
00:14:08,140 --> 00:14:05,660
constraints to these theoretical

382
00:14:09,100 --> 00:14:08,150
calculations and ultimately the results

383
00:14:11,470 --> 00:14:09,110
from these outgassing

384
00:14:13,270 --> 00:14:11,480
experiments will help inform the initial

385
00:14:16,060 --> 00:14:13,280
boundary conditions on these low mass

386
00:14:17,900 --> 00:14:16,070
planet atmosphere compositions thank you

387
00:14:24,249 --> 00:14:17,910
he'll take

388
00:14:39,769 --> 00:14:37,639

Thank You Maggie um if I remember

389
00:14:42,050 --> 00:14:39,779
correctly and probably Laura knows this

390
00:14:45,259 --> 00:14:42,060
better than I do but in their paper into

391
00:14:48,650 --> 00:14:45,269
in 2004 they do compare with experiments

392
00:14:50,420 --> 00:14:48,660
and then fine very good much with with a

393
00:14:52,220 --> 00:14:50,430
certain between the experiments and the

394
00:14:54,139 --> 00:14:52,230
model so I'm wondering what's difference

395
00:14:55,879 --> 00:14:54,149
between I mean they were not using

396
00:14:57,470 --> 00:14:55,889
meteor eyes they were using rocks from

397
00:14:58,970 --> 00:14:57,480
the earth but they do compare with

398
00:15:00,410 --> 00:14:58,980
friends and so that's certainly true

399
00:15:02,840 --> 00:15:00,420
people have definitely heated up

400
00:15:04,759 --> 00:15:02,850
meteorites before but no one has done it

401
00:15:07,009 --> 00:15:04,769
in such a way at looking at this goal in

402
00:15:08,360 --> 00:15:07,019
mind so a lot of the old older meteorite

403
00:15:10,249 --> 00:15:08,370
heating experiments are trying to

404
00:15:12,259 --> 00:15:10,259
understand what happens when meteorites

405
00:15:14,090 --> 00:15:12,269
enter the Earth's atmosphere so they're

406
00:15:16,850 --> 00:15:14,100
looking at like flash heating really

407
00:15:18,439 --> 00:15:16,860
rapid heating events and so yeah so some

408
00:15:20,179 --> 00:15:18,449
of the results are similar and that's

409
00:15:22,069 --> 00:15:20,189
really awesome but what we're trying to

410
00:15:24,559 --> 00:15:22,079
do is to try to create an experimental

411
00:15:26,600 --> 00:15:24,569
environment that really replicates the

412
00:15:28,579 --> 00:15:26,610
outgassing process as opposed to just

413
00:15:30,290 --> 00:15:28,589

like doing it from what the

414
00:15:32,269 --> 00:15:30,300
cosmochemistry perspective which was

415
00:15:34,129 --> 00:15:32,279
trying to understand more about like the

416
00:15:36,110 --> 00:15:34,139
specific process the meteorites went

417
00:15:37,100 --> 00:15:36,120
through to get to earth but yes that's

418
00:15:40,759 --> 00:15:37,110
very true well you're definitely not the

419
00:15:44,650 --> 00:15:40,769
first people to heat meteorites okay

420
00:15:49,400 --> 00:15:47,360
Nico and Miguel is there a way that you

421
00:15:50,629 --> 00:15:49,410
can break the mass degeneracy with some

422
00:15:52,670 --> 00:15:50,639
other something other than the mass

423
00:15:54,110 --> 00:15:52,680
spectrometer that's a great question

424
00:15:56,900 --> 00:15:54,120
that's something that we would like to

425
00:15:58,189 --> 00:15:56,910
look at in the future for instance we'd

426
00:16:01,269 --> 00:15:58,199
love to be able to maybe like get a

427
00:16:03,410 --> 00:16:01,279
spectra of the gas as its flowing

428
00:16:05,120 --> 00:16:03,420
there's definitely also ways to break

429
00:16:07,069 --> 00:16:05,130
the degeneracy just within the mass

430
00:16:09,679 --> 00:16:07,079
spectrometer itself like we can look at

431
00:16:11,720 --> 00:16:09,689
a variety of Peaks around say like the

432
00:16:14,090 --> 00:16:11,730
carbon monoxide line to differentiate

433
00:16:15,319 --> 00:16:14,100
what's due to carbon versus nitrogen so

434
00:16:16,579 --> 00:16:15,329
I think we're gonna start with that and

435
00:16:21,740 --> 00:16:16,589
then we're gonna look into some other

436
00:16:25,230 --> 00:16:21,750
experimental setups as well okay thank