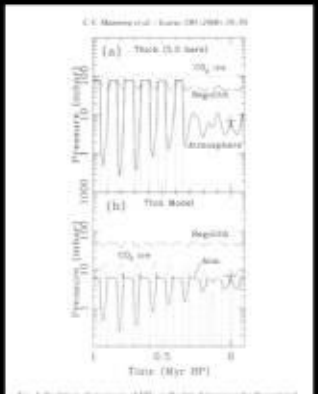
Obliquity History



- Thick initial atmosphere result in large swings in greenhouse warming due to obliquity variations
- Atmosphere would change little in response to obliquity variations if initially thin

1
00:00:07,039 --> 00:00:03,830
welcome to the first of our astrobiology

2
00:00:10,370 --> 00:00:07,049
seminar series for this quarter as a bit

3
00:00:14,390 --> 00:00:10,380
of future advertising next week we'll be

4
00:00:17,840 --> 00:00:14,400
having Dave Chris from JPL talking about

5
00:00:20,480 --> 00:00:17,850
his new mission investigating new space

6
00:00:25,130 --> 00:00:20,490
mission investigating carbon dioxide

7
00:00:27,710 --> 00:00:25,140
levels and secret sources and sinks in

8
00:00:29,990 --> 00:00:27,720
the carbon cycle of the earth very

9
00:00:33,229 --> 00:00:30,000
relevant to astrobiology because carbon

10
00:00:37,729 --> 00:00:33,239
fluxes are all important for regulating

11
00:00:39,799 --> 00:00:37,739
planetary temperatures of course the

12
00:00:42,459 --> 00:00:39,809
other great volatile that's of vital

13
00:00:46,970 --> 00:00:42,469

importance to astrobiology is water and

14
00:00:50,180 --> 00:00:46,980
this week seminar will be on water and

15
00:00:54,319 --> 00:00:50,190
where it's where it's not why it's not

16
00:00:56,900 --> 00:00:54,329
on Mars being given to us by Erika honey

17
00:00:59,090 --> 00:00:56,910
of Earth and Space Sciences the space

18
00:01:02,240 --> 00:00:59,100
physics group in Earth and Space

19
00:01:03,590 --> 00:01:02,250
Sciences at University of Washington she

20
00:01:09,490 --> 00:01:03,600
comes to us from a physics background

21
00:01:15,170 --> 00:01:09,500
she did her PhD here with Robert winley

22
00:01:18,010 --> 00:01:15,180
investigating modeling of micro magneto

23
00:01:20,630 --> 00:01:18,020
spheres on the moon and was the first to

24
00:01:23,840 --> 00:01:20,640
demonstrate the potential for such

25
00:01:28,850 --> 00:01:23,850
things by modeling subsequently to that

26
00:01:30,830 --> 00:01:28,860
she was post-op of sorts in ESS in the

27
00:01:34,219 --> 00:01:30,840
space physics group and has recently

28
00:01:38,359 --> 00:01:34,229
been appointed research assistant

29
00:01:41,600 --> 00:01:38,369
professor in space physics and she's her

30
00:01:44,980 --> 00:01:41,610
interest generally in magnetospheric

31
00:01:47,389 --> 00:01:44,990
modeling and other suchlike processes

32
00:01:50,120 --> 00:01:47,399
she'll be talking about Mars where did

33
00:01:53,510 --> 00:01:50,130
all the water go very good thank you yes

34
00:01:55,999 --> 00:01:53,520
so I'm going to be discussing the sort

35
00:01:57,980 --> 00:01:56,009
of a space physicist take on where did

36
00:02:00,530 --> 00:01:57,990
all the water go at mars and i'll be

37
00:02:03,350 --> 00:02:00,540
presenting numerical simulations that

38
00:02:05,149 --> 00:02:03,360

will address what is that what is the

39
00:02:07,010 --> 00:02:05,159
sort of some of the things we have to

40
00:02:11,290 --> 00:02:07,020
consider when when

41
00:02:13,369 --> 00:02:11,300
looking at loss of water to space and

42
00:02:15,140 --> 00:02:13,379
trying to figure out how much of the

43
00:02:16,460 --> 00:02:15,150
water was lost to space and how much of

44
00:02:18,860 --> 00:02:16,470
the water that was present under an

45
00:02:21,830 --> 00:02:18,870
early Mother's is still residing at Mars

46
00:02:24,740 --> 00:02:21,840
possibly in what this picture hasn't

47
00:02:27,050 --> 00:02:24,750
been interpreted as icebergs does

48
00:02:28,550 --> 00:02:27,060
covered icebergs on Mars so it's most of

49
00:02:30,140 --> 00:02:28,560
the water in form of just being locked

50
00:02:31,610 --> 00:02:30,150
up in the surface and it's just not

51
00:02:36,890 --> 00:02:31,620
terribly visible or did a lot of it

52
00:02:38,420 --> 00:02:36,900
leave and get lost to space so I'm going

53
00:02:39,949 --> 00:02:38,430
to talk about my some of the simulations

54
00:02:41,870 --> 00:02:39,959
but first know that we're all on a the

55
00:02:43,850 --> 00:02:41,880
same background I want to give us sort

56
00:02:45,289 --> 00:02:43,860
of a short history of Mars and talk

57
00:02:47,300 --> 00:02:45,299
about some of the physical processes

58
00:02:50,539 --> 00:02:47,310
that could have contributed to loss of

59
00:02:52,370 --> 00:02:50,549
water to space remembering the geologic

60
00:02:54,800 --> 00:02:52,380
epoch SAT Mars is really easy because

61
00:02:57,559 --> 00:02:54,810
there's only three the first one is the

62
00:03:00,259 --> 00:02:57,569
nokia naira valent essentially the era

63
00:03:02,059 --> 00:03:00,269

begins with formation and the end of the

64
00:03:05,960 --> 00:03:02,069
area is associated with the end of heavy

65
00:03:07,640 --> 00:03:05,970
bombardment this time is associated when

66
00:03:10,580 --> 00:03:07,650
when water was thought to be fairly

67
00:03:12,949 --> 00:03:10,590
prevalent on Mars and there would have

68
00:03:15,920 --> 00:03:12,959
been active erosion there possibly even

69
00:03:18,470 --> 00:03:15,930
lakes and oceans present there would

70
00:03:20,629 --> 00:03:18,480
have an intense volcanic activity there

71
00:03:23,420 --> 00:03:20,639
was a dynamo generated magnetic field

72
00:03:25,220 --> 00:03:23,430
when exactly that shut off is a an area

73
00:03:28,370 --> 00:03:25,230
of active research and a big question

74
00:03:30,680 --> 00:03:28,380
and impacts associated with heavy

75
00:03:33,460 --> 00:03:30,690
bombardment would have driven eighty to

76
00:03:36,710 --> 00:03:33,470
ninety five percent of atmospheric loss

77
00:03:38,599 --> 00:03:36,720
the second era is the Hesperian era and

78
00:03:40,699 --> 00:03:38,609
this is essentially a trend the

79
00:03:42,949 --> 00:03:40,709
beginning of this area associated with

80
00:03:44,750 --> 00:03:42,959
the end of heavy bombardment and the end

81
00:03:46,879 --> 00:03:44,760
of it is a little fuzzy because its

82
00:03:49,370 --> 00:03:46,889
associated with people with when people

83
00:03:51,259 --> 00:03:49,380
think liquid water cease to become

84
00:03:53,449 --> 00:03:51,269
stable on the surface so we're not

85
00:03:56,030 --> 00:03:53,459
entirely sure when that's at it's sort

86
00:03:58,670 --> 00:03:56,040
of a general idea and this is sort of a

87
00:04:01,670 --> 00:03:58,680
transition time from Mars going from

88
00:04:04,430 --> 00:04:01,680

having in the early time of being having

89
00:04:06,349 --> 00:04:04,440
a lot of active erosion plenty of water

90
00:04:09,920 --> 00:04:06,359
to the more air in time that we know of

91
00:04:11,960 --> 00:04:09,930
today any sort of water bring prevalent

92
00:04:14,509 --> 00:04:11,970
on Mars would have been more episodic in

93
00:04:16,999 --> 00:04:14,519
nature then the water would have been

94
00:04:18,430 --> 00:04:17,009
migrating essentially my migrating to

95
00:04:20,380 --> 00:04:18,440
the polar caps and under

96
00:04:23,490 --> 00:04:20,390
held and there may have been transit a

97
00:04:25,930 --> 00:04:23,500
transitional or episodic river activity

98
00:04:28,090 --> 00:04:25,940
during this time there may have been a

99
00:04:31,930 --> 00:04:28,100
resurgence of the Dynamo magnetic field

100
00:04:33,190 --> 00:04:31,940
it's that's a question and most of the

101
00:04:34,720 --> 00:04:33,200
atmospheric loss that would have

102
00:04:36,100 --> 00:04:34,730
occurred during this time and water loss

103
00:04:38,800 --> 00:04:36,110
would have been thrown more sort of a

104
00:04:40,960 --> 00:04:38,810
mass selective method and sort of to

105
00:04:43,030 --> 00:04:40,970
sort of illustrate some of the episodic

106
00:04:45,040 --> 00:04:43,040
and breakout flooding you see here we

107
00:04:46,720 --> 00:04:45,050
this is a picture of a fluval fan that

108
00:04:50,230 --> 00:04:46,730
would have formed that formed during

109
00:04:52,330 --> 00:04:50,240
this hesperian area era and then the

110
00:04:54,760 --> 00:04:52,340
final era is the current era which is

111
00:04:57,490 --> 00:04:54,770
the amazonian era which goes from this

112
00:05:01,030 --> 00:04:57,500
fuzzy time of when water stopped being

113
00:05:03,160 --> 00:05:01,040

prevalent to present and this is this is

114
00:05:06,880 --> 00:05:03,170
an arid pit time there is there's

115
00:05:09,040 --> 00:05:06,890
occasional breakout activity but for the

116
00:05:11,350 --> 00:05:09,050
most part it's dry dusty conditions and

117
00:05:13,840 --> 00:05:11,360
there may have been occasional volcanic

118
00:05:15,220 --> 00:05:13,850
activity but we do know that there is

119
00:05:17,650 --> 00:05:15,230
something actually happening not just

120
00:05:19,210 --> 00:05:17,660
sort of in the the short geologic of

121
00:05:21,610 --> 00:05:19,220
time but even on the very short time

122
00:05:23,830 --> 00:05:21,620
scales this picture shows a crater wall

123
00:05:25,840 --> 00:05:23,840
an image of a crater wall taken by mars

124
00:05:28,420 --> 00:05:25,850
global surveyor and the two images are

125
00:05:30,790 --> 00:05:28,430
the exact same but spot six years apart

126
00:05:33,280 --> 00:05:30,800
and you can already sort of see just

127
00:05:34,930 --> 00:05:33,290
from looking at this inmates it looks

128
00:05:36,820 --> 00:05:34,940
like you see these crevasses associated

129
00:05:40,810 --> 00:05:36,830
with some sort of flowing possibly a

130
00:05:42,400 --> 00:05:40,820
aqueous fluid movement and but the real

131
00:05:45,400 --> 00:05:42,410
kicker is when you look at this the

132
00:05:47,350 --> 00:05:45,410
second image taken most recently is what

133
00:05:48,909 --> 00:05:47,360
looks like a new deposit so even though

134
00:05:50,740 --> 00:05:48,919
the concurrent conditions are not

135
00:05:52,990 --> 00:05:50,750
favorable for water there does appear to

136
00:05:57,670 --> 00:05:53,000
be some sort of occasional transitionary

137
00:05:59,740 --> 00:05:57,680
em activity so just how unfavourable are

138
00:06:02,460 --> 00:05:59,750

the current conditions for water on Mars

139
00:06:06,100 --> 00:06:02,470
this is the phase diagram for water and

140
00:06:07,930 --> 00:06:06,110
the yellow rectangle here indicates sort

141
00:06:10,000 --> 00:06:07,940
of the range of current conditions that

142
00:06:11,530 --> 00:06:10,010
can be found on Mars the highest

143
00:06:13,120 --> 00:06:11,540
pressure that are associated with the

144
00:06:14,530 --> 00:06:13,130
top of the rectangle are the conditions

145
00:06:17,200 --> 00:06:14,540
that would be found at the bottom of

146
00:06:19,170 --> 00:06:17,210
Valley Marineris during the summer the

147
00:06:21,210 --> 00:06:19,180
pub conditions that

148
00:06:22,650 --> 00:06:21,220
see at the bottom of the rectangle are

149
00:06:25,170 --> 00:06:22,660
the conditions if you're at the top of

150
00:06:29,219 --> 00:06:25,180
Olympus Mons and you can sorta see this

151
00:06:32,730 --> 00:06:29,229
little spot right here where possibly

152
00:06:35,100 --> 00:06:32,740
you may get liquid water forming that's

153
00:06:37,230 --> 00:06:35,110
why we do occasionally see it the other

154
00:06:39,180 --> 00:06:37,240
thing that this graph points out is that

155
00:06:41,969 --> 00:06:39,190
in the past if you wanted to have

156
00:06:43,680 --> 00:06:41,979
written stable liquid water just raising

157
00:06:45,540 --> 00:06:43,690
the surface temperature is not going to

158
00:06:47,100 --> 00:06:45,550
get to their all you'll do is the

159
00:06:49,080 --> 00:06:47,110
strands a shrimper somewhere around here

160
00:06:51,510 --> 00:06:49,090
over to here you're going to go straight

161
00:06:55,140 --> 00:06:51,520
from ice to vapor in order to have

162
00:06:56,520 --> 00:06:55,150
stable liquid water on Mars you needed

163
00:06:58,710 --> 00:06:56,530

to have what you need to have more

164
00:07:02,850 --> 00:06:58,720
pressure in the past which means poor

165
00:07:05,100 --> 00:07:02,860
atmosphere so what would that of

166
00:07:06,749 --> 00:07:05,110
atmosphere have been what was the past

167
00:07:08,969 --> 00:07:06,759
atmospheric condition composition

168
00:07:10,950 --> 00:07:08,979
possibly life so what I've got shown

169
00:07:13,200 --> 00:07:10,960
here are the are the atmospheric

170
00:07:14,939 --> 00:07:13,210
compositions for the three terrestrial

171
00:07:16,080 --> 00:07:14,949
planets that actually have a thick

172
00:07:18,330 --> 00:07:16,090
atmosphere I've left with Mercury

173
00:07:20,490 --> 00:07:18,340
Ralphie here and you'll notice but I'm

174
00:07:22,980 --> 00:07:20,500
sort of just doing the toppling person

175
00:07:25,170 --> 00:07:22,990
then our life build earth is actually

176
00:07:27,350 --> 00:07:25,180
the oddball out in this in this

177
00:07:31,110 --> 00:07:27,360
comparison that both of units and Mars

178
00:07:32,939 --> 00:07:31,120
primarily CO 2 atmospheres so if you

179
00:07:34,520 --> 00:07:32,949
think well okay maybe if we use Venus's

180
00:07:37,980 --> 00:07:34,530
not having lost much of its atmosphere

181
00:07:40,050 --> 00:07:37,990
then we could assume maybe that if Mars

182
00:07:44,040 --> 00:07:40,060
had a thicker atmosphere in the past it

183
00:07:45,570 --> 00:07:44,050
would have been primarily co2 but there

184
00:07:48,300 --> 00:07:45,580
was originally thought to be a problem

185
00:07:49,980 --> 00:07:48,310
with that entered that line of logic so

186
00:07:52,560 --> 00:07:49,990
if you use sort of a conservative

187
00:07:54,810 --> 00:07:52,570
estimate of what you might want to have

188
00:07:57,570 --> 00:07:54,820

for a thick a thick atmosphere to have

189
00:08:01,100 --> 00:07:57,580
water minimally stable us ooh maybe

190
00:08:03,689 --> 00:08:01,110
about 150 mil more just for reference

191
00:08:07,430 --> 00:08:03,699
conditions are about seven eight bars of

192
00:08:10,590 --> 00:08:07,440
co2 yo conventional wisdom with you

193
00:08:13,560 --> 00:08:10,600
to atmospheric you would get when I'm

194
00:08:15,900 --> 00:08:13,570
told were favorable position on the

195
00:08:17,550 --> 00:08:15,910
phase diagram first for water and you

196
00:08:20,100 --> 00:08:17,560
again in a greenhouse effect associated

197
00:08:21,750 --> 00:08:20,110
with the co2 but if there is a lot of

198
00:08:24,360 --> 00:08:21,760
water president you should be generating

199
00:08:26,280 --> 00:08:24,370
carbonate rock everywhere and there is

200
00:08:28,140 --> 00:08:26,290
very little carbonate rocks eating on

201
00:08:31,470 --> 00:08:28,150
the surface so this was thought to be

202
00:08:35,940 --> 00:08:31,480
evidence that the thicker atmosphere was

203
00:08:39,630 --> 00:08:35,950
not primarily co2 then Mars exploration

204
00:08:42,270 --> 00:08:39,640
Rovers landed specifically opportunity

205
00:08:44,430 --> 00:08:42,280
landed in Marathi meridiani planum and

206
00:08:47,100 --> 00:08:44,440
I'm sure we've all seen this absolutely

207
00:08:50,880 --> 00:08:47,110
beautiful picture of the layered outcrop

208
00:08:53,490 --> 00:08:50,890
at the top of Eagle crater and as Mars

209
00:08:56,370 --> 00:08:53,500
as murder got closer to the rock outcrop

210
00:08:58,350 --> 00:08:56,380
it's all these little round rocks that

211
00:09:00,390 --> 00:08:58,360
have been termed blueberries and just as

212
00:09:01,590 --> 00:09:00,400
a warning this picture is a false color

213
00:09:04,410 --> 00:09:01,600

image and the blueberries are not

214
00:09:06,870 --> 00:09:04,420
actually blue blue color can indicates

215
00:09:09,150 --> 00:09:06,880
composition specifically that their iron

216
00:09:11,280 --> 00:09:09,160
or hematite rich now is actually the

217
00:09:14,520 --> 00:09:11,290
reason why meridiani planum was chosen

218
00:09:15,900 --> 00:09:14,530
as a landing site from space it was

219
00:09:18,390 --> 00:09:15,910
indicated that there was a fair amount

220
00:09:20,400 --> 00:09:18,400
of grey hematite in that region and

221
00:09:22,470 --> 00:09:20,410
great imitator typically only farms in

222
00:09:25,170 --> 00:09:22,480
the presence of water so that's why this

223
00:09:28,320 --> 00:09:25,180
site was chosen and here it is in the

224
00:09:30,120 --> 00:09:28,330
form of blueberries when they look much

225
00:09:32,940 --> 00:09:30,130
camp got much closer this is a zoomed in

226
00:09:34,320 --> 00:09:32,950
picture of these blueberries that what

227
00:09:36,450 --> 00:09:34,330
these what these blueberries really are

228
00:09:40,130 --> 00:09:36,460
is something called concretions they

229
00:09:44,130 --> 00:09:40,140
form when iron precipitates out of rock

230
00:09:46,740 --> 00:09:44,140
when it when that rock is is saturated

231
00:09:49,110 --> 00:09:46,750
with water so there they indicate the

232
00:09:51,510 --> 00:09:49,120
presence of water and there in every

233
00:09:54,660 --> 00:09:51,520
single layer of the rock layer doubt

234
00:09:57,630 --> 00:09:54,670
crops that are the in Eagle crater but

235
00:09:59,700 --> 00:09:57,640
more importantly the surrounding rock

236
00:10:01,920 --> 00:09:59,710
around these blueberries is something

237
00:10:03,720 --> 00:10:01,930
called jira site Jerry site is a type of

238
00:10:07,020 --> 00:10:03,730

rock that only forms when the aqueous

239
00:10:08,520 --> 00:10:07,030
fluid has a pH of less than 5 and on

240
00:10:10,800 --> 00:10:08,530
earth that typically actually only forms

241
00:10:14,640 --> 00:10:10,810
and when the pH is a range of 123 so

242
00:10:16,710 --> 00:10:14,650
basically battery acid so that water

243
00:10:18,270 --> 00:10:16,720
that was that was present when these

244
00:10:20,440 --> 00:10:18,280
blueberries form well there may have

245
00:10:23,320 --> 00:10:20,450
been a lot of it at times

246
00:10:25,930 --> 00:10:23,330
it was very acidic water and if you have

247
00:10:27,970 --> 00:10:25,940
a very thick co2 atmosphere and very

248
00:10:30,040 --> 00:10:27,980
acidic water you will not cycle the co2

249
00:10:32,560 --> 00:10:30,050
through the water and create carbonate

250
00:10:35,050 --> 00:10:32,570
rocks so the thought that the atmosphere

251
00:10:36,880 --> 00:10:35,060
could not have been sickly a thick co2

252
00:10:39,400 --> 00:10:36,890
atmosphere is now that evidence is

253
00:10:41,320 --> 00:10:39,410
proven to be false and for way with

254
00:10:43,240 --> 00:10:41,330
regard to life one of the things this

255
00:10:45,940 --> 00:10:43,250
indicates is that if life was either

256
00:10:47,740 --> 00:10:45,950
developing at this time possibly or was

257
00:10:49,750 --> 00:10:47,750
already present it would have had to

258
00:10:52,780 --> 00:10:49,760
deal with it with the conditions that

259
00:10:58,690 --> 00:10:52,790
were not only very acidic but oxidizing

260
00:11:00,280 --> 00:10:58,700
saline and intermittently wet so with

261
00:11:02,860 --> 00:11:00,290
that sort of idea of where some of the

262
00:11:04,990 --> 00:11:02,870
past history of Mars now let us talk

263
00:11:06,250 --> 00:11:05,000

about that through Mars is history what

264
00:11:09,190 --> 00:11:06,260
are some of the loss or hiding

265
00:11:12,370 --> 00:11:09,200
mechanisms by which we can see water can

266
00:11:14,320 --> 00:11:12,380
sort of disappear from our view so the

267
00:11:16,570 --> 00:11:14,330
first and most obvious possible hiding

268
00:11:17,800 --> 00:11:16,580
mechanisms is in the polar caps and you

269
00:11:19,300 --> 00:11:17,810
can actually see from this picture I

270
00:11:20,950 --> 00:11:19,310
have up in the corner this is a picture

271
00:11:22,780 --> 00:11:20,960
taken during the salt the southern

272
00:11:27,100 --> 00:11:22,790
winter and we see a very prominent

273
00:11:29,620 --> 00:11:27,110
southern polar cap there's water ice in

274
00:11:32,380 --> 00:11:29,630
the caps with a co2 frost and both the

275
00:11:35,340 --> 00:11:32,390
north and south polar the the persistent

276
00:11:37,780 --> 00:11:35,350
caps are about three kilometers thick

277
00:11:39,190 --> 00:11:37,790
another possible hiding mechanism is

278
00:11:40,780 --> 00:11:39,200
relates to that picture I showed at the

279
00:11:42,970 --> 00:11:40,790
beginning which is what was have

280
00:11:45,160 --> 00:11:42,980
interpreted as does covered I Sparks is

281
00:11:47,290 --> 00:11:45,170
it could just be locked up in permafrost

282
00:11:49,690 --> 00:11:47,300
or in the soil and you can actually hide

283
00:11:54,730 --> 00:11:49,700
about ten you could hide tens of meters

284
00:11:57,640 --> 00:11:54,740
of water through that method or it could

285
00:11:59,860 --> 00:11:57,650
be lost to space and we know that that

286
00:12:01,480 --> 00:11:59,870
there has been lost to space because we

287
00:12:03,850 --> 00:12:01,490
have measured a significant amount of

288
00:12:05,320 --> 00:12:03,860

mass fraction ization mass fraction

289
00:12:07,270 --> 00:12:05,330
ization will only occur when you have

290
00:12:09,070 --> 00:12:07,280
something that's a mass selective method

291
00:12:10,930 --> 00:12:09,080
which is only occurs when you're losing

292
00:12:13,540 --> 00:12:10,940
it to space but with the caveat that you

293
00:12:17,350 --> 00:12:13,550
can modify it somewhat by the surface

294
00:12:19,840 --> 00:12:17,360
reservoirs so it's sort of different

295
00:12:22,270 --> 00:12:19,850
that said now I'm going to focus on

296
00:12:24,400 --> 00:12:22,280
different types of loss mechanisms that

297
00:12:26,470 --> 00:12:24,410
can occur and the first being a thermal

298
00:12:28,150 --> 00:12:26,480
mechanism thermal mechanisms so the

299
00:12:30,310 --> 00:12:28,160
first type of thermal mechanism is the

300
00:12:31,230 --> 00:12:30,320
one that was primary the primary lost

301
00:12:32,940 --> 00:12:31,240
mechanism not

302
00:12:34,410 --> 00:12:32,950
Elliot Mars but all of the early

303
00:12:36,180 --> 00:12:34,420
terrestrial planets right after

304
00:12:38,550 --> 00:12:36,190
formation and that's hydrodynamic

305
00:12:40,500 --> 00:12:38,560
outflow but early atmospheres would have

306
00:12:43,530 --> 00:12:40,510
been primarily light species

307
00:12:45,510 --> 00:12:43,540
specifically hydrogen and that species

308
00:12:47,760 --> 00:12:45,520
would have been hot and as it was

309
00:12:50,130 --> 00:12:47,770
escaping to the fact that it thermal

310
00:12:51,660 --> 00:12:50,140
velocity was korea had greater than this

311
00:12:53,610 --> 00:12:51,670
escape velocity and had enough energy

312
00:12:55,199 --> 00:12:53,620
due to the fact that the atmospheres

313
00:12:56,910 --> 00:12:55,209

were very thick it would have just

314
00:12:58,350 --> 00:12:56,920
removed the collision time scales would

315
00:13:00,090 --> 00:12:58,360
have been very short and it would have

316
00:13:03,900 --> 00:13:00,100
just drank all of the other heavier

317
00:13:06,480 --> 00:13:03,910
elements with it so this would been a

318
00:13:10,190 --> 00:13:06,490
non nuttin this is a non mass selective

319
00:13:12,060 --> 00:13:10,200
method another chief early source of

320
00:13:14,310 --> 00:13:12,070
mechanism for loss would have been

321
00:13:17,160 --> 00:13:14,320
impact to rosen impactors occurring

322
00:13:18,750 --> 00:13:17,170
during the era of heavy bombardment you

323
00:13:21,150 --> 00:13:18,760
get a vapor plume coming off of the

324
00:13:22,680 --> 00:13:21,160
impact vapor plume is essentially a

325
00:13:25,740 --> 00:13:22,690
small kiss scale version of hydrodynamic

326
00:13:27,960 --> 00:13:25,750
outflow the temperatures are high it's

327
00:13:30,150 --> 00:13:27,970
very thick very collisional that light

328
00:13:31,949 --> 00:13:30,160
species that are being there being lost

329
00:13:34,949 --> 00:13:31,959
will describe the heavier species out

330
00:13:39,510 --> 00:13:34,959
with it also it's a source of volatile

331
00:13:41,760 --> 00:13:39,520
so you get material back to a mass

332
00:13:43,500 --> 00:13:41,770
selective loss mechanism in thermal

333
00:13:45,389 --> 00:13:43,510
mechanisms thermal or jeans escape and

334
00:13:47,760 --> 00:13:45,399
this will incur went what's the

335
00:13:49,440 --> 00:13:47,770
atmosphere has become thinner and then

336
00:13:51,060 --> 00:13:49,450
you can in your diffusion time scales

337
00:13:53,370 --> 00:13:51,070
are short compared to your collision

338
00:13:57,090 --> 00:13:53,380

time scales in that case you have

339
00:13:59,160 --> 00:13:57,100
species where the thermal velocity is

340
00:14:01,350 --> 00:13:59,170
greater than the skate velocity such as

341
00:14:06,079 --> 00:14:01,360
hydrogen per snail mail escape whereas

342
00:14:08,730 --> 00:14:06,089
if oxygen it's gravitationally bound

343
00:14:11,550 --> 00:14:08,740
this is fiction from the hydrodynamic

344
00:14:14,430 --> 00:14:11,560
that I thought that that was also normal

345
00:14:16,860 --> 00:14:14,440
eating it is but the hydrodynamic escape

346
00:14:19,530 --> 00:14:16,870
that one you have collisions so the

347
00:14:21,600 --> 00:14:19,540
hydrogen the so boxes so oxygen or

348
00:14:23,370 --> 00:14:21,610
something heavy may have normally what

349
00:14:25,920 --> 00:14:23,380
under its under normal conditions have

350
00:14:27,329 --> 00:14:25,930
been it's dragging exactly would have

351
00:14:29,579 --> 00:14:27,339
been below escape velocity but the

352
00:14:32,400 --> 00:14:29,589
collisions will pull it out so it's a

353
00:14:34,230 --> 00:14:32,410
collisional effect whereas when jeans

354
00:14:36,690 --> 00:14:34,240
escape or thermal escape start taking

355
00:14:38,310 --> 00:14:36,700
over you the collision time scale is

356
00:14:40,980 --> 00:14:38,320
much longer so you don't you don't have

357
00:14:42,900 --> 00:14:40,990
hydrogen pulling the heavier zout so

358
00:14:46,610 --> 00:14:42,910
it's just leaving it's leaving and

359
00:14:51,720 --> 00:14:50,130
so nonthermal mechanisms include

360
00:14:53,160 --> 00:14:51,730
photochemical escape and this is

361
00:14:55,200 --> 00:14:53,170
actually a very important escape

362
00:14:57,720 --> 00:14:55,210
mechanism occurring in the current day

363
00:15:01,650 --> 00:14:57,730

atmosphere and what occurs is you have

364
00:15:04,790 --> 00:15:01,660
co2 will be ionized by ultraviolet rays

365
00:15:07,560 --> 00:15:04,800
from the Sun and in a very fairly quick

366
00:15:09,930 --> 00:15:07,570
process photog well through photolysis

367
00:15:13,320 --> 00:15:09,940
it will interact with an oxygen neutral

368
00:15:15,900 --> 00:15:13,330
creating 02 plus and a co neutral this

369
00:15:18,600 --> 00:15:15,910
is the reason why co2 is the dominant

370
00:15:22,140 --> 00:15:18,610
neutral at Mars but 0 2 plus is the

371
00:15:23,730 --> 00:15:22,150
dominant eye on it Mars o 2 plus can

372
00:15:26,280 --> 00:15:23,740
then interact with an electron and

373
00:15:28,650 --> 00:15:26,290
through dissociative recombination break

374
00:15:32,220 --> 00:15:28,660
apart the molecular bond and create two

375
00:15:33,360 --> 00:15:32,230
very energetic oxygens of atoms the star

376
00:15:35,340 --> 00:15:33,370
indicates that they're very energetic

377
00:15:37,800 --> 00:15:35,350
this will create what's called a hot

378
00:15:39,720 --> 00:15:37,810
oxygen Corona this is these are very

379
00:15:42,180 --> 00:15:39,730
energetic oxygen they escape very

380
00:15:44,610 --> 00:15:42,190
quickly and very easily from Mars and

381
00:15:46,500 --> 00:15:44,620
just make a corona of neutrals around

382
00:15:49,140 --> 00:15:46,510
the planet this Corona has been met

383
00:15:51,330 --> 00:15:49,150
definitely measured up to five planetary

384
00:15:52,950 --> 00:15:51,340
radii away from the planet and it's

385
00:15:54,930 --> 00:15:52,960
probably actually present up to ten

386
00:15:58,700 --> 00:15:54,940
radii away from the planet so this makes

387
00:16:01,620 --> 00:15:58,710
a very large Corona around the planet

388
00:16:03,330 --> 00:16:01,630

another mechanism which then temps up

389
00:16:06,420 --> 00:16:03,340
takes over is once you've got this

390
00:16:08,550 --> 00:16:06,430
neutral Corona around the planet there

391
00:16:09,990 --> 00:16:08,560
are I ons coming from the Sun in form of

392
00:16:12,020 --> 00:16:10,000
solar wind and there's magnetic field

393
00:16:14,130 --> 00:16:12,030
that's laced through that solar wind

394
00:16:15,960 --> 00:16:14,140
it's a ver still a very tenuous

395
00:16:17,400 --> 00:16:15,970
atmosphere so the Mutual's will not

396
00:16:19,830 --> 00:16:17,410
interact with the ions through

397
00:16:21,840 --> 00:16:19,840
pollutions and because they're neutral

398
00:16:24,630 --> 00:16:21,850
they will not feel the effect of the

399
00:16:27,720 --> 00:16:24,640
magnetic field but once they get ionized

400
00:16:29,910 --> 00:16:27,730
by solar ultraviolet radiation they will

401
00:16:31,380 --> 00:16:29,920
instantly be picked up by that magnetic

402
00:16:33,780 --> 00:16:31,390
field they will instantly feel it and

403
00:16:36,360 --> 00:16:33,790
then start being carried downstream and

404
00:16:38,250 --> 00:16:36,370
with the solar wind when they can either

405
00:16:40,980 --> 00:16:38,260
just be carried downstream and go flying

406
00:16:44,370 --> 00:16:40,990
past Mars and be completely lost or

407
00:16:46,920 --> 00:16:44,380
since it's a heavy element in the form

408
00:16:48,990 --> 00:16:46,930
of a plus they can react the atmosphere

409
00:16:51,330 --> 00:16:49,000
and they do so with much more momentum

410
00:16:53,790 --> 00:16:51,340
and energy then if it was a hydrogen ion

411
00:16:55,590 --> 00:16:53,800
and in doing so they can either break

412
00:16:57,220 --> 00:16:55,600
apart molecular bonds or they can

413
00:17:00,820 --> 00:16:57,230

actually just kick heavies

414
00:17:02,200 --> 00:17:00,830
out of the atmosphere if they kick the

415
00:17:04,540 --> 00:17:02,210
heavies out of the atmosphere that's a

416
00:17:06,010 --> 00:17:04,550
process called sputtering and this may

417
00:17:09,270 --> 00:17:06,020
be have may have been an important

418
00:17:11,170 --> 00:17:09,280
process in the early atmosphere and

419
00:17:14,050 --> 00:17:11,180
because we have ions that are

420
00:17:15,870 --> 00:17:14,060
interacting with the ionosphere near

421
00:17:17,920 --> 00:17:15,880
near the bound near the planet at

422
00:17:19,960 --> 00:17:17,930
boundaries that you'll get there will be

423
00:17:22,480 --> 00:17:19,970
waves plasma waves that will interact at

424
00:17:24,700 --> 00:17:22,490
that boundary there's both removal or

425
00:17:26,290 --> 00:17:24,710
associated with this this plasma waves

426
00:17:32,470 --> 00:17:26,300
and instead of instability can also lead

427
00:17:35,950 --> 00:17:32,480
to loss so just to recap it to recap of

428
00:17:37,930 --> 00:17:35,960
the lost history at Mars is that it that

429
00:17:40,000 --> 00:17:37,940
formation the original atmosphere was

430
00:17:42,550 --> 00:17:40,010
delivered by impactors and outgassing

431
00:17:44,620 --> 00:17:42,560
from the created material this

432
00:17:46,330 --> 00:17:44,630
hydrodynamic escape which was non mass

433
00:17:48,250 --> 00:17:46,340
selective would then take over and

434
00:17:50,770 --> 00:17:48,260
stripping most of the early atmosphere

435
00:17:52,480 --> 00:17:50,780
until it stripping when the early

436
00:17:55,060 --> 00:17:52,490
atmosphere until most of the hydrogen

437
00:17:56,620 --> 00:17:55,070
was gone that impact erosion would have

438
00:17:59,250 --> 00:17:56,630

would take over as the dominant lock

439
00:18:02,230 --> 00:17:59,260
myth lost mechanism until the end of

440
00:18:06,030 --> 00:18:02,240
heavy bombardment ended but it would

441
00:18:08,410 --> 00:18:06,040
also lead to a source of volatiles and

442
00:18:10,330 --> 00:18:08,420
then the wild cards come in that you

443
00:18:12,030 --> 00:18:10,340
have the secondary atmosphere that was

444
00:18:14,920 --> 00:18:12,040
there after the end of heavy bombardment

445
00:18:17,080 --> 00:18:14,930
may have possibly been predicted by a

446
00:18:18,520 --> 00:18:17,090
global magnetic field and may have also

447
00:18:21,190 --> 00:18:18,530
been supplemented by some additional

448
00:18:23,680 --> 00:18:21,200
volcanic activity and then jeans escape

449
00:18:26,170 --> 00:18:23,690
and photo chemical processes would then

450
00:18:28,300 --> 00:18:26,180
take over and be become the dominant

451
00:18:30,910 --> 00:18:28,310
lost mechanism for Mutual's and still be

452
00:18:32,950 --> 00:18:30,920
that today and solar wind will have

453
00:18:35,650 --> 00:18:32,960
become lost mechanisms will come the

454
00:18:39,070 --> 00:18:35,660
dominant loss mechanism for ions so what

455
00:18:40,780 --> 00:18:39,080
about this magnetic field at Mars up

456
00:18:43,960 --> 00:18:40,790
until the arrival of Mars Global

457
00:18:46,750 --> 00:18:43,970
Surveyor it was not entirely known what

458
00:18:49,090 --> 00:18:46,760
the nature of Mars's magnetic field was

459
00:18:50,920 --> 00:18:49,100
it was there was something measured and

460
00:18:53,620 --> 00:18:50,930
it was weak but nobody was quite sure if

461
00:18:54,970 --> 00:18:53,630
it was a weak global dynamo or I've even

462
00:18:56,800 --> 00:18:54,980
seen papers where people thought well

463
00:18:57,539 --> 00:18:56,810

maybe Phobos the moons Phobos was

464
00:18:59,489 --> 00:18:57,549
magnetized

465
00:19:00,899 --> 00:18:59,499
that's what they were picking up but

466
00:19:02,669 --> 00:19:00,909
with Mars levels are there they're all

467
00:19:03,869 --> 00:19:02,679
to prove without a doubt that the

468
00:19:06,239 --> 00:19:03,879
magnetic field that was being measured

469
00:19:08,609 --> 00:19:06,249
was actually in the form of magnetized

470
00:19:10,109 --> 00:19:08,619
rock on the surface the name that it

471
00:19:11,639 --> 00:19:10,119
goes by the name magnetic anomalies and

472
00:19:13,710 --> 00:19:11,649
this is the first sort of measurement of

473
00:19:16,729 --> 00:19:13,720
these magnetic anomalies the color

474
00:19:19,019 --> 00:19:16,739
indicates a magnetic field measured it

475
00:19:20,609 --> 00:19:19,029
felt to be at the surface that was

476
00:19:21,810 --> 00:19:20,619
measured it at a higher atmosphere so

477
00:19:24,779 --> 00:19:21,820
they don't know exactly what it is at

478
00:19:28,470 --> 00:19:24,789
the surface look shown on top of a

479
00:19:30,330 --> 00:19:28,480
topography map and because most people

480
00:19:32,279 --> 00:19:30,340
don't except for space businesses work

481
00:19:34,440 --> 00:19:32,289
in units of Nana Tesla just as a

482
00:19:36,899 --> 00:19:34,450
reference the Earth's global magnetic

483
00:19:39,509 --> 00:19:36,909
dynamo driven global magnetic field at

484
00:19:41,340 --> 00:19:39,519
the surface at the equator is 30,000

485
00:19:43,320 --> 00:19:41,350
Nana Tesla so only about ten times

486
00:19:45,419 --> 00:19:43,330
larger than this so these are very

487
00:19:47,399 --> 00:19:45,429
strong magnetic anomalies which is why

488
00:19:50,549 --> 00:19:47,409

they was ambiguous nobody thought they

489
00:19:52,739 --> 00:19:50,559
could be quite this strong here's

490
00:19:54,119 --> 00:19:52,749
another showing of them because you

491
00:19:56,099 --> 00:19:54,129
couldn't really get an idea where these

492
00:19:57,840 --> 00:19:56,109
magnetic anomalies work this is a

493
00:20:00,269 --> 00:19:57,850
picture of the color indicates the

494
00:20:01,979 --> 00:20:00,279
topography of Mars and the black and

495
00:20:04,739 --> 00:20:01,989
white contour is in to create the

496
00:20:06,419 --> 00:20:04,749
magnetic field strength both inward and

497
00:20:08,099 --> 00:20:06,429
outward and you'll see that the magnetic

498
00:20:10,289 --> 00:20:08,109
field is primarily in the southern

499
00:20:12,899 --> 00:20:10,299
hemisphere and associated with this

500
00:20:15,869 --> 00:20:12,909
heavily cratered older terrain of the

501
00:20:17,759 --> 00:20:15,879
southern highlands but there is some

502
00:20:19,970 --> 00:20:17,769
there are some magnetic anomalies in the

503
00:20:21,989 --> 00:20:19,980
northern lowlands in the newer train

504
00:20:23,340 --> 00:20:21,999
most of them don't show up on this

505
00:20:26,099 --> 00:20:23,350
resolution they tend to be much smaller

506
00:20:28,200 --> 00:20:26,109
and you also say that appears that the

507
00:20:31,320 --> 00:20:28,210
large impact basins of Hellas and our

508
00:20:32,849 --> 00:20:31,330
jar appeared to be unmagnetized the fact

509
00:20:34,799 --> 00:20:32,859
that Hellas and our jar appear to be

510
00:20:38,249 --> 00:20:34,809
unmagnetized has been used to suggest

511
00:20:40,970 --> 00:20:38,259
that the Mars Global dynamo turned off

512
00:20:44,220 --> 00:20:40,980
prior to the end of heavy bombardment

513
00:20:46,409 --> 00:20:44,230

but it's possible that hellas and our

514
00:20:48,330 --> 00:20:46,419
jar are actually magnetized but the

515
00:20:50,489 --> 00:20:48,340
signal is just so incoherent that you

516
00:20:51,989 --> 00:20:50,499
can't be measured at space so it's not

517
00:20:53,279 --> 00:20:51,999
until we actually get something on the

518
00:20:54,749 --> 00:20:53,289
surface that measures we couldn't know

519
00:20:57,239 --> 00:20:54,759
for sure and the fact that there are

520
00:20:59,279 --> 00:20:57,249
magnetic anomalies up in the more newer

521
00:21:01,979 --> 00:20:59,289
terrain of the northern highlands naw

522
00:21:04,979 --> 00:21:01,989
northern lowlands has suggested to some

523
00:21:09,659 --> 00:21:04,989
that maybe the dynamo restarted later on

524
00:21:11,220 --> 00:21:09,669
in the Hesperian era and then the other

525
00:21:13,860 --> 00:21:11,230
wild card that comes in

526
00:21:15,720 --> 00:21:13,870
this is the obliquity obliquity is their

527
00:21:17,760 --> 00:21:15,730
angle at which the rotation vector of a

528
00:21:20,909 --> 00:21:17,770
planet makes with the normal to the

529
00:21:23,220 --> 00:21:20,919
ecliptic plane currently Mars is rotated

530
00:21:25,500 --> 00:21:23,230
obliquity angles about 20 degrees but

531
00:21:27,510 --> 00:21:25,510
simulations have shown that due to the

532
00:21:29,220 --> 00:21:27,520
fact that Mars does not have only a few

533
00:21:31,409 --> 00:21:29,230
puny little moons babosa need us and

534
00:21:34,140 --> 00:21:31,419
does not have a large moon its obliquity

535
00:21:36,510 --> 00:21:34,150
won't have Brooke floated around and

536
00:21:38,760 --> 00:21:36,520
oscillated up to maybe even about 50

537
00:21:41,370 --> 00:21:38,770
degrees up to about 10 million years ago

538
00:21:44,159 --> 00:21:41,380

and possibly even more even earlier on

539
00:21:46,380 --> 00:21:44,169
the fact that the earth has a large moon

540
00:21:49,500 --> 00:21:46,390
has helped stabilize its rotation axis

541
00:21:52,049 --> 00:21:49,510
so it's liquid rotates just a little bit

542
00:21:54,720 --> 00:21:52,059
and as it is suggest about that's one of

543
00:22:00,960 --> 00:21:54,730
the actually helpers that make life on

544
00:22:04,650 --> 00:22:00,970
Earth a little more possible so some

545
00:22:07,500 --> 00:22:04,660
initial results are a research into what

546
00:22:10,560 --> 00:22:07,510
obliquity changes can do to Mars was by

547
00:22:13,289 --> 00:22:10,570
Manning's um McKay and zolani and

548
00:22:15,539 --> 00:22:13,299
they've looked at how obliquity changes

549
00:22:18,000 --> 00:22:15,549
would affect this variations in the

550
00:22:19,470 --> 00:22:18,010
atmospheric density and showing this

551
00:22:21,330 --> 00:22:19,480
plot is to showing for a thicker

552
00:22:23,640 --> 00:22:21,340
atmosphere which they claim is being

553
00:22:27,270 --> 00:22:23,650
five bars so much thicker than we

554
00:22:29,280 --> 00:22:27,280
assumed first earlier on or a thin model

555
00:22:31,320 --> 00:22:29,290
thin atmospheric models of something

556
00:22:34,620 --> 00:22:31,330
less than five bars of atmosphere how

557
00:22:37,860 --> 00:22:34,630
that how co2 would have moved from being

558
00:22:39,780 --> 00:22:37,870
trapped in regolith and co2 ice to being

559
00:22:41,430 --> 00:22:39,790
in the atmosphere and found that if they

560
00:22:43,590 --> 00:22:41,440
started with a very thick atmosphere

561
00:22:46,530 --> 00:22:43,600
obliquity the obliquity changes would

562
00:22:48,600 --> 00:22:46,540
charge would lead to large changes in

563
00:22:50,549 --> 00:22:48,610

global warming and large variations in

564
00:22:52,500 --> 00:22:50,559
the atmospheric temperatures but if they

565
00:22:53,610 --> 00:22:52,510
started with a thin atmosphere that

566
00:22:57,390 --> 00:22:53,620
there wouldn't be quite as much

567
00:22:59,310 --> 00:22:57,400
variation so with that background

568
00:23:02,340 --> 00:22:59,320
they'll know now talk about the solar

569
00:23:04,710 --> 00:23:02,350
wind interaction at Mars so this is a

570
00:23:06,690 --> 00:23:04,720
little cartoon of what happens so i can

571
00:23:10,890 --> 00:23:06,700
define some of the terms the solar wind

572
00:23:13,830 --> 00:23:10,900
is presidential ii the sun's atmosphere

573
00:23:15,780 --> 00:23:13,840
boiling off into space and it's charged

574
00:23:17,280 --> 00:23:15,790
particles so it's a plasma so it's ions

575
00:23:19,860 --> 00:23:17,290
and electrons there's no neutrals as

576
00:23:23,370 --> 00:23:19,870
it's a plasma is highly conductive and

577
00:23:24,340 --> 00:23:23,380
when it boils off into space it will

578
00:23:26,560 --> 00:23:24,350
drag the soul

579
00:23:28,659 --> 00:23:26,570
magnetic field with it into space and

580
00:23:32,380 --> 00:23:28,669
forming what's called the interplanetary

581
00:23:34,770 --> 00:23:32,390
magnetic field or IMF the current

582
00:23:37,600 --> 00:23:34,780
conditions are such that the solar wind

583
00:23:40,419 --> 00:23:37,610
what as its traveling out into space is

584
00:23:42,610 --> 00:23:40,429
moving with a speed that is faster than

585
00:23:45,039 --> 00:23:42,620
its inherent sales be so when it runs

586
00:23:48,250 --> 00:23:45,049
into an obstacle such as a planet like

587
00:23:50,860 --> 00:23:48,260
Mars or the earth and slows down it will

588
00:23:54,190 --> 00:23:50,870

form a bow shock and it's not well for

589
00:23:56,440 --> 00:23:54,200
shown in this picture as it sure as the

590
00:23:59,710 --> 00:23:56,450
the kinetic energy is converted into

591
00:24:01,630 --> 00:23:59,720
thermal energy it will that it will form

592
00:24:03,610 --> 00:24:01,640
a hot layer of plasma call to magneto

593
00:24:06,669 --> 00:24:03,620
sheath which is sort of shown in this

594
00:24:09,310 --> 00:24:06,679
region right here with whole lot of wavy

595
00:24:13,020 --> 00:24:09,320
mature waves on the magnetic field so

596
00:24:15,460 --> 00:24:13,030
this the white lines of magnetic IMF

597
00:24:17,740 --> 00:24:15,470
eventually the solar wind will enter it

598
00:24:19,899 --> 00:24:17,750
will come in contact with the highly

599
00:24:21,640 --> 00:24:19,909
conducting I atmosphere of a planet it's

600
00:24:23,799 --> 00:24:21,650
got an atmosphere or in the case of

601
00:24:25,720 --> 00:24:23,809
something like the moon does not have an

602
00:24:27,730 --> 00:24:25,730
atmosphere it will just keep plowing in

603
00:24:30,100 --> 00:24:27,740
if it comes in contact with a

604
00:24:32,169 --> 00:24:30,110
nightosphere old then it can because the

605
00:24:34,120 --> 00:24:32,179
magnetic field associated with the solar

606
00:24:36,310 --> 00:24:34,130
wind cannot transit through this

607
00:24:43,060 --> 00:24:36,320
conductor it will pile up and then

608
00:24:45,430 --> 00:24:43,070
eventually slide around the side so what

609
00:24:47,350 --> 00:24:45,440
are some of the solar wind possible

610
00:24:50,110 --> 00:24:47,360
possible solar wind conditions in the

611
00:24:54,010 --> 00:24:50,120
past from the Sun well we know

612
00:24:58,299 --> 00:24:54,020
essentially that a young son is an

613
00:24:59,950 --> 00:24:58,309

active son and that in the past the

614
00:25:03,310 --> 00:24:59,960
ultraviolet and x-ray flux would have

615
00:25:05,200 --> 00:25:03,320
been larger that will lead to more

616
00:25:07,120 --> 00:25:05,210
ionization of atmospheres would have led

617
00:25:09,520 --> 00:25:07,130
to more heating so an honest here would

618
00:25:11,830 --> 00:25:09,530
have been heated it expanded inflated

619
00:25:14,409 --> 00:25:11,840
and increasing scale heights in and

620
00:25:18,070 --> 00:25:14,419
extend expanding out this hot oxygen

621
00:25:19,659 --> 00:25:18,080
Corona that Mars possesses the solar

622
00:25:21,880 --> 00:25:19,669
wind would have been elevated by what

623
00:25:23,770 --> 00:25:21,890
elevated what I mean is that the dip the

624
00:25:25,779 --> 00:25:23,780
density of material flowing off of the

625
00:25:27,970 --> 00:25:25,789
Sun would have been higher or larger and

626
00:25:29,799 --> 00:25:27,980
the speeds at which they come off would

627
00:25:31,659 --> 00:25:29,809
have been larger as well that

628
00:25:33,460 --> 00:25:31,669
interplanetary magnetic field would have

629
00:25:36,010 --> 00:25:33,470
been stronger as well but it works out

630
00:25:36,230 --> 00:25:36,020
that the pick up a pick up of ions in

631
00:25:38,030 --> 00:25:36,240
this

632
00:25:42,799 --> 00:25:38,040
perona associated with that would have

633
00:25:45,230 --> 00:25:42,809
actually decreased though and then we

634
00:25:46,820 --> 00:25:45,240
have our wild cards of when did the

635
00:25:50,240 --> 00:25:46,830
planetary magnetic field certain with

636
00:25:53,840 --> 00:25:50,250
the global man dynamo turn off and how

637
00:25:55,280 --> 00:25:53,850
to obliquity changes figure into this so

638
00:25:57,049 --> 00:25:55,290

one of the problems is if you're going

639
00:25:59,030 --> 00:25:57,059
to be modeling something you want to

640
00:26:00,200 --> 00:25:59,040
have some data to validate your model

641
00:26:04,820 --> 00:26:00,210
against and prove that it's really

642
00:26:06,500 --> 00:26:04,830
correct um we don't know exactly what

643
00:26:08,960 --> 00:26:06,510
the solar wind conditions were in the

644
00:26:11,840 --> 00:26:08,970
early side we can only look at it at

645
00:26:14,120 --> 00:26:11,850
solar types cars in estimating and we

646
00:26:17,030 --> 00:26:14,130
definitely don't have any data from then

647
00:26:19,640 --> 00:26:17,040
either so the best thing we can do is

648
00:26:22,549 --> 00:26:19,650
use current date forms as analogues by

649
00:26:25,580 --> 00:26:22,559
which to test our models so how good of

650
00:26:27,290 --> 00:26:25,590
that of an approximation is that so I'm

651
00:26:28,940 --> 00:26:27,300
going to go through and the and talk

652
00:26:30,680 --> 00:26:28,950
about the sort of the four main

653
00:26:33,740 --> 00:26:30,690
characteristics of the Sun of the Sun

654
00:26:37,040 --> 00:26:33,750
for both storms current date storms and

655
00:26:39,860 --> 00:26:37,050
what we know for looking at solar-type

656
00:26:45,010 --> 00:26:39,870
stars that are at least a billion years

657
00:26:47,480 --> 00:26:45,020
younger than the Sun so we know that the

658
00:26:49,340 --> 00:26:47,490
ultraviolet to x-ray flux will it was

659
00:26:52,400 --> 00:26:49,350
probably between three to 50 times

660
00:26:54,610 --> 00:26:52,410
larger during a flare that's associated

661
00:26:57,110 --> 00:26:54,620
with a solar with a storm that

662
00:26:58,970 --> 00:26:57,120
ultraviolet and x-ray flux can increase

663
00:27:02,690 --> 00:26:58,980

from ten to a hundred times its nominal

664
00:27:04,010 --> 00:27:02,700
of range the solar wind speed in the

665
00:27:06,560 --> 00:27:04,020
past was probably about four times

666
00:27:08,660 --> 00:27:06,570
larger than current values during a

667
00:27:12,049 --> 00:27:08,670
storm the speed will increase by about

668
00:27:14,090 --> 00:27:12,059
two to five times solar wind density was

669
00:27:17,060 --> 00:27:14,100
probably somewhere between 15 to 40

670
00:27:19,190 --> 00:27:17,070
times larger in the past during storm

671
00:27:21,580 --> 00:27:19,200
conditions you can get dense increases

672
00:27:24,020 --> 00:27:21,590
in density there about five times larger

673
00:27:26,299 --> 00:27:24,030
IMS strength is probably about 10 times

674
00:27:30,320 --> 00:27:26,309
stronger at each given planet in the

675
00:27:31,700 --> 00:27:30,330
past and during storm conditions the IMF

676
00:27:35,210 --> 00:27:31,710
strength can increase by about five

677
00:27:36,680 --> 00:27:35,220
times interplanetary magnetic field this

678
00:27:39,350 --> 00:27:36,690
magnetic field that's laced throughout

679
00:27:42,470 --> 00:27:39,360
the solar wind uh now there's a caveat

680
00:27:43,500 --> 00:27:42,480
here in the past the soap both the solar

681
00:27:45,380 --> 00:27:43,510
wind speed and

682
00:27:47,880 --> 00:27:45,390
density would have been elevated

683
00:27:50,580 --> 00:27:47,890
typically not all of the time but

684
00:27:53,100 --> 00:27:50,590
typically during a solar storm during a

685
00:27:54,870 --> 00:27:53,110
solar storm when the speed increases the

686
00:27:57,480 --> 00:27:54,880
density decreases so they're usually

687
00:27:58,800 --> 00:27:57,490
inversely correlated it doesn't happen

688
00:28:01,620 --> 00:27:58,810

all the time so you have to be very

689
00:28:03,930 --> 00:28:01,630
careful with which storms you pick to

690
00:28:05,430 --> 00:28:03,940
use this doll as analogues because not

691
00:28:09,870 --> 00:28:05,440
all storms are created equal in that

692
00:28:12,090 --> 00:28:09,880
respect so how do we do this modeling we

693
00:28:15,390 --> 00:28:12,100
use something that we call a 3d multi

694
00:28:17,280 --> 00:28:15,400
fluid model the physical the formulas

695
00:28:18,930 --> 00:28:17,290
that govern the physics of solar wind

696
00:28:21,510 --> 00:28:18,940
interacting with ayanna spears and

697
00:28:23,730 --> 00:28:21,520
atmospheres of planets cannot be solved

698
00:28:27,720 --> 00:28:23,740
analytically so we have to solve the set

699
00:28:34,560 --> 00:28:27,730
of equations numerically and what we do

700
00:28:36,480 --> 00:28:34,570
is sorry um what we do is we solve we

701
00:28:38,850 --> 00:28:36,490
have this track several different ion

702
00:28:41,040 --> 00:28:38,860
species for the most part it's usually

703
00:28:43,350 --> 00:28:41,050
free once associated with the solar wind

704
00:28:46,230 --> 00:28:43,360
and one or two associated with in

705
00:28:48,630 --> 00:28:46,240
atmosphere of a planet or moon and for

706
00:28:51,480 --> 00:28:48,640
each ion species we solve conservation

707
00:28:53,820 --> 00:28:51,490
of mass momentum and energy equations

708
00:28:55,530 --> 00:28:53,830
numerically on a grid because we have

709
00:28:57,540 --> 00:28:55,540
this magnetic field that's both laced

710
00:28:59,670 --> 00:28:57,550
through the solar wind and may be

711
00:29:01,440 --> 00:28:59,680
associated with the planet itself we

712
00:29:05,160 --> 00:29:01,450
have to solve the induction equation and

713
00:29:07,800 --> 00:29:05,170

then on a sort of large scale we assume

714
00:29:11,640 --> 00:29:07,810
charge neutrality and a generalized

715
00:29:14,580 --> 00:29:11,650
Ohm's law as well so I to some of the

716
00:29:17,010 --> 00:29:14,590
simulation results look like so why is

717
00:29:19,650 --> 00:29:17,020
he here this sort of blue blob with some

718
00:29:22,170 --> 00:29:19,660
green spots on it is indicating Mars but

719
00:29:24,000 --> 00:29:22,180
the color variation is to indicate the

720
00:29:25,650 --> 00:29:24,010
fact that i have actually modeled the

721
00:29:27,330 --> 00:29:25,660
anomaly put that an ominous magnetic

722
00:29:29,730 --> 00:29:27,340
field into the model I'll talk about

723
00:29:31,380 --> 00:29:29,740
this a little bit more later is this is

724
00:29:33,780 --> 00:29:31,390
oriented such that this the North Pole

725
00:29:36,150 --> 00:29:33,790
is up here South Pole is here solar wind

726
00:29:38,730 --> 00:29:36,160
is coming in from the left hand side and

727
00:29:40,800 --> 00:29:38,740
the interplanetary magnetic field is

728
00:29:42,600 --> 00:29:40,810
arranged such that it's pointing into

729
00:29:45,990 --> 00:29:42,610
the board and these give sort of the

730
00:29:47,610 --> 00:29:46,000
these are nominal average quiet

731
00:29:48,480 --> 00:29:47,620
conditions solar wind conditions you

732
00:29:50,940 --> 00:29:48,490
don't have to worry about the numbers

733
00:29:54,270 --> 00:29:50,950
too much what's shown here is the color

734
00:29:55,690 --> 00:29:54,280
is a log of the ionospheric density in a

735
00:29:58,360 --> 00:29:55,700
plane going through them

736
00:30:00,490 --> 00:29:58,370
noon-midnight meridian so tactic North

737
00:30:03,730 --> 00:30:00,500
Col here so noon over here midnight over

738
00:30:05,620 --> 00:30:03,740

here the black contours indicate solar

739
00:30:07,990 --> 00:30:05,630
wind density so this is actually

740
00:30:09,879 --> 00:30:08,000
tracking out this bow shot how I picked

741
00:30:11,649 --> 00:30:09,889
value so they pick out this bow shop so

742
00:30:13,600 --> 00:30:11,659
this indicates where the solar wind

743
00:30:15,070 --> 00:30:13,610
comes in and then we out the inner edge

744
00:30:18,250 --> 00:30:15,080
is sort of where it's sort of petering

745
00:30:20,560 --> 00:30:18,260
out and one of the first things you sort

746
00:30:22,539 --> 00:30:20,570
of see is this is the tube that itís

747
00:30:23,680 --> 00:30:22,549
great density and bow shock sort of

748
00:30:25,120 --> 00:30:23,690
track each other in the northern

749
00:30:26,799 --> 00:30:25,130
hemisphere but in the southern

750
00:30:29,200 --> 00:30:26,809
hemisphere there's a significant portion

751
00:30:30,970 --> 00:30:29,210
of ionospheric material it's outside of

752
00:30:33,700 --> 00:30:30,980
the bow shock so this is basically in

753
00:30:35,620 --> 00:30:33,710
this unperturbed region where the solar

754
00:30:39,430 --> 00:30:35,630
wind is traveling it in is if there was

755
00:30:42,009 --> 00:30:39,440
nothing there so why is that occur it

756
00:30:43,299 --> 00:30:42,019
occurs because the fact that ions in the

757
00:30:46,149 --> 00:30:43,309
presence of the presence of a magnetic

758
00:30:48,490 --> 00:30:46,159
field will gyrate in a circle about that

759
00:30:50,259 --> 00:30:48,500
magnetic field and it will they dry rate

760
00:30:51,580 --> 00:30:50,269
gyrate and such that for this magnetic

761
00:30:56,200 --> 00:30:51,590
field they will go in a counterclockwise

762
00:30:57,940 --> 00:30:56,210
direction and if you were to launch they

763
00:30:59,950 --> 00:30:57,950

say launched an ion from the northern

764
00:31:04,240 --> 00:30:59,960
hemisphere it would gyrate around and

765
00:31:06,190 --> 00:31:04,250
then re impact the surface but if you

766
00:31:07,690 --> 00:31:06,200
were to launch that same ion from the

767
00:31:09,009 --> 00:31:07,700
southern hemisphere it would start

768
00:31:11,590 --> 00:31:09,019
gyrating among the magnetic field and

769
00:31:12,970 --> 00:31:11,600
then we're never run into nothing it

770
00:31:14,799 --> 00:31:12,980
would just go right out into the solar

771
00:31:17,379 --> 00:31:14,809
wind in which and where the conditions

772
00:31:19,810 --> 00:31:17,389
are different and then the this orbit

773
00:31:22,480 --> 00:31:19,820
about the size of the gyro motion would

774
00:31:24,850 --> 00:31:22,490
change so anything sort of launched from

775
00:31:26,320 --> 00:31:24,860
here can it or bleed out the southern

776
00:31:28,299 --> 00:31:26,330
hemisphere can bleed out into the solar

777
00:31:31,450 --> 00:31:28,309
wind and this is what's called pick up

778
00:31:33,399 --> 00:31:31,460
this is the pickup region now to

779
00:31:36,669 --> 00:31:33,409
righties I did a series of simulations

780
00:31:39,039 --> 00:31:36,679
where I kept a single parameter synthase

781
00:31:40,720 --> 00:31:39,049
I either kept the solar wind conditions

782
00:31:42,789 --> 00:31:40,730
the same and move the orientation of

783
00:31:45,399 --> 00:31:42,799
Mars or I kept the orientation of Mars

784
00:31:47,830 --> 00:31:45,409
the same and varied a single parameter

785
00:31:50,649 --> 00:31:47,840
in the solar ring just to figure out how

786
00:31:52,480 --> 00:31:50,659
solar wind well itís great loss and

787
00:31:54,190 --> 00:31:52,490
solar wind precipitation into Mars as

788
00:31:55,840 --> 00:31:54,200

ionosphere change with different

789
00:31:57,879 --> 00:31:55,850
parameters because it's not a given that

790
00:32:00,710 --> 00:31:57,889
they would that they would vary linearly

791
00:32:03,110 --> 00:32:00,720
and to highlight that I have sir

792
00:32:05,210 --> 00:32:03,120
series here this indicates essentially

793
00:32:07,190 --> 00:32:05,220
this is the same nearly the same

794
00:32:09,230 --> 00:32:07,200
conditions is that first lot so we have

795
00:32:11,840 --> 00:32:09,240
solar wind coming in from the slide here

796
00:32:15,020 --> 00:32:11,850
North Pole of Mars here South Pole here

797
00:32:16,730 --> 00:32:15,030
the color and the color is plane is

798
00:32:17,990 --> 00:32:16,740
running through them is the ina spheric

799
00:32:20,149 --> 00:32:18,000
density running through the

800
00:32:22,399 --> 00:32:20,159
noon-midnight Meridian the black contour

801
00:32:24,950 --> 00:32:22,409
lines indicate the bow shock and this

802
00:32:27,430 --> 00:32:24,960
this is sort of my nominal case normal

803
00:32:30,200 --> 00:32:27,440
solar wind conditions what we assume the

804
00:32:33,169 --> 00:32:30,210
primary ionospheric composition is of 0

805
00:32:35,539 --> 00:32:33,179
plus 0 2 plus in the I know skirt when I

806
00:32:39,110 --> 00:32:35,549
only change the mass of the ionosphere

807
00:32:41,390 --> 00:32:39,120
so I went from 0 to plus 20 plus the

808
00:32:44,060 --> 00:32:41,400
solar wind precipitation rate and the

809
00:32:47,149 --> 00:32:44,070
INA spheric loss rate deep both decrease

810
00:32:49,669 --> 00:32:47,159
by thirty percent name thing that might

811
00:32:52,220 --> 00:32:49,679
seem counterintuitive if you decrease

812
00:32:54,470 --> 00:32:52,230
the mass of the ionospheric component

813
00:32:55,940 --> 00:32:54,480

therefore its escape velocity should be

814
00:32:58,850 --> 00:32:55,950
lower so you would think well maybe that

815
00:33:01,279 --> 00:32:58,860
it should have large larger escape rate

816
00:33:03,740 --> 00:33:01,289
what but what turns out to be more

817
00:33:05,810 --> 00:33:03,750
important is the fact that it's mounted

818
00:33:07,279 --> 00:33:05,820
pick up actually decreases and you can

819
00:33:09,049 --> 00:33:07,289
see that by comparing the southern

820
00:33:11,450 --> 00:33:09,059
portion here that's outside the bow

821
00:33:13,940 --> 00:33:11,460
shock for this light ionospheric mass

822
00:33:15,980 --> 00:33:13,950
case the pickup region is smaller

823
00:33:18,890 --> 00:33:15,990
because the pickup region is smaller

824
00:33:20,600 --> 00:33:18,900
there is less loss this goes back to the

825
00:33:23,060 --> 00:33:20,610
discussion of what was the past

826
00:33:25,399 --> 00:33:23,070
ionospheric composition that was not

827
00:33:28,220 --> 00:33:25,409
just an interesting thought exercise it

828
00:33:30,409 --> 00:33:28,230
is an actual important parameter to try

829
00:33:33,590 --> 00:33:30,419
to figure out because it is crucial to

830
00:33:35,720 --> 00:33:33,600
get the the mass effects right in order

831
00:33:40,190 --> 00:33:35,730
to figure the mass right in order to

832
00:33:42,049 --> 00:33:40,200
figure out loss rates another men when I

833
00:33:44,750 --> 00:33:42,059
started from the north sort of nominal

834
00:33:47,029 --> 00:33:44,760
conditions and then merely doubled the

835
00:33:49,850 --> 00:33:47,039
solar wind speed we saw I saw that the

836
00:33:51,830 --> 00:33:49,860
finest very gloss rates increased by

837
00:33:54,560 --> 00:33:51,840
twice and again associated with this

838
00:33:58,010 --> 00:33:54,570

increased pick up so it's in the the

839
00:33:59,930 --> 00:33:58,020
solar wind speed seems to scale linearly

840
00:34:03,289 --> 00:33:59,940
with loss rates or the loss rate scale

841
00:34:04,940 --> 00:34:03,299
linearly with with solar wind speeds so

842
00:34:08,270 --> 00:34:04,950
it's talking about the the anomalous

843
00:34:10,010 --> 00:34:08,280
magnetic field this is a picture of how

844
00:34:11,899 --> 00:34:10,020
it what it looks like in the simulation

845
00:34:14,899 --> 00:34:11,909
so this is just purely magnitude

846
00:34:16,760 --> 00:34:14,909
it's a 400 kilometer so higher than the

847
00:34:19,250 --> 00:34:16,770
picture I was shown indicating before of

848
00:34:20,720 --> 00:34:19,260
the surface field you see primarily in

849
00:34:22,760 --> 00:34:20,730
the southern hemisphere although there's

850
00:34:26,930 --> 00:34:22,770
a little bit of a strong one of nerdy

851
00:34:29,419 --> 00:34:26,940
equator so this kind of comes now just

852
00:34:31,760 --> 00:34:29,429
do the ina straight loss rates vary as a

853
00:34:33,500 --> 00:34:31,770
function of how the anomalies are

854
00:34:34,849 --> 00:34:33,510
oriented if they're facing directly into

855
00:34:36,470 --> 00:34:34,859
the solar wind if they're pointed sort

856
00:34:38,020 --> 00:34:36,480
of off to the side this this is

857
00:34:40,940 --> 00:34:38,030
important with respect to obliquity

858
00:34:43,159 --> 00:34:40,950
because when the obliquity is around 50

859
00:34:46,279 --> 00:34:43,169
degrees these anomalies will never face

860
00:34:48,230 --> 00:34:46,289
directly into the solar wind what I'm

861
00:34:49,970 --> 00:34:48,240
showing here is 44 different happens to

862
00:34:52,220 --> 00:34:49,980
be 44 different cases for the solar wind

863
00:34:54,230 --> 00:34:52,230

and where I ran with this the anomalies

864
00:34:56,389 --> 00:34:54,240
pointed directly facing into the solar

865
00:34:58,760 --> 00:34:56,399
wind so they are all aligned along the

866
00:35:01,520 --> 00:34:58,770
new Meridian what i'm showing is solar

867
00:35:03,920 --> 00:35:01,530
wind density at 400 kilometers so what

868
00:35:06,140 --> 00:35:03,930
this means is when it's blue the region

869
00:35:08,420 --> 00:35:06,150
is sort of anomalous magnetic field

870
00:35:11,059 --> 00:35:08,430
protects the region from the solar wind

871
00:35:12,440 --> 00:35:11,069
and when it's red it means it has an

872
00:35:14,809 --> 00:35:12,450
increased amount of solar wind

873
00:35:17,559 --> 00:35:14,819
penetrating into that area and you can

874
00:35:19,760 --> 00:35:17,569
see that when I just merely rotated the

875
00:35:22,789 --> 00:35:19,770
interplanetary magnetic field by 90

876
00:35:24,380 --> 00:35:22,799
degrees the ridge protected regions sort

877
00:35:26,930 --> 00:35:24,390
of moved around a little bit and some of

878
00:35:29,000 --> 00:35:26,940
the enhanced regions moved around but

879
00:35:31,220 --> 00:35:29,010
there are also still regions where that

880
00:35:33,079 --> 00:35:31,230
that were protected from one IMF

881
00:35:35,140 --> 00:35:33,089
orientation remained protected from the

882
00:35:37,309 --> 00:35:35,150
solar wind and regions that were

883
00:35:39,470 --> 00:35:37,319
enhanced for one orientation remain

884
00:35:43,010 --> 00:35:39,480
enhanced so places you probably don't

885
00:35:45,559 --> 00:35:43,020
want to build a Martian base and then

886
00:35:49,730 --> 00:35:45,569
when I went to sort of more active storm

887
00:35:51,260 --> 00:35:49,740
as old son kite conditions everything's

888
00:35:53,380 --> 00:35:51,270

were to get smeared out but you still

889
00:35:57,769 --> 00:35:53,390
have regions that are a bit protected

890
00:35:59,750 --> 00:35:57,779
the main thing i found was that the loss

891
00:36:02,390 --> 00:35:59,760
rates do not seem to very much with

892
00:36:05,539 --> 00:36:02,400
anomaly orientation now that could be

893
00:36:07,849 --> 00:36:05,549
because whatever plasma it was deflected

894
00:36:09,289 --> 00:36:07,859
room say this region was just funneled

895
00:36:11,480 --> 00:36:09,299
to another region so when you calculate

896
00:36:12,500 --> 00:36:11,490
things globally you didn't see a net

897
00:36:16,460 --> 00:36:12,510
change because they were just moved

898
00:36:19,279 --> 00:36:16,470
around another possibility was the fact

899
00:36:22,190 --> 00:36:19,289
that the sort of grid site the sort of

900
00:36:23,370 --> 00:36:22,200
bar shaped pattern or a bar code type

901
00:36:26,400 --> 00:36:23,380
pattern associated with

902
00:36:28,829 --> 00:36:26,410
the anomalies what is at was actually on

903
00:36:30,720 --> 00:36:28,839
the order of the grid resolution in the

904
00:36:32,759 --> 00:36:30,730
numerical simulations we have to solve

905
00:36:35,940 --> 00:36:32,769
our about our numerical simulations on a

906
00:36:37,620 --> 00:36:35,950
grid and they were about comparable so

907
00:36:39,930 --> 00:36:37,630
it was possible that I may be just not

908
00:36:41,759 --> 00:36:39,940
resolving the anomalies so it didn't

909
00:36:43,559 --> 00:36:41,769
really so even though this made it look

910
00:36:44,609 --> 00:36:43,569
like they were there they really didn't

911
00:36:47,370 --> 00:36:44,619
look like they were there in the

912
00:36:49,170 --> 00:36:47,380
simulations so in order to resolve this

913
00:36:50,910 --> 00:36:49,180

issue whether it was just moving plasma

914
00:36:53,460 --> 00:36:50,920
round or this or this effect wasn't

915
00:36:56,819 --> 00:36:53,470
resolved I did higher resolution

916
00:37:00,210 --> 00:36:56,829
simulation of the solar wind interaction

917
00:37:02,460 --> 00:37:00,220
and so what we see here is the sort of

918
00:37:04,230 --> 00:37:02,470
sphere colored sphere is again Mars and

919
00:37:06,990 --> 00:37:04,240
the color indicates the magnetic field

920
00:37:09,509 --> 00:37:07,000
you can see up in the sort of close to

921
00:37:11,069 --> 00:37:09,519
the equator this sort of hot region of

922
00:37:13,680 --> 00:37:11,079
high magnetic field that I pointed out

923
00:37:15,359 --> 00:37:13,690
early earlier the really strong

924
00:37:17,099 --> 00:37:15,369
anomalies errs that are down here is

925
00:37:18,779 --> 00:37:17,109
closer to the southern hemisphere and

926
00:37:21,809 --> 00:37:18,789
you can't see them because they're off

927
00:37:24,299 --> 00:37:21,819
plane the plane the color material are

928
00:37:26,160 --> 00:37:24,309
the color planes here are either solar

929
00:37:28,529 --> 00:37:26,170
wind density ionospheric hydrogen

930
00:37:31,019 --> 00:37:28,539
density or is carrying oxygen density in

931
00:37:33,240 --> 00:37:31,029
the noon meridian and then also showing

932
00:37:34,589 --> 00:37:33,250
magnetic field lines and you can see

933
00:37:36,809 --> 00:37:34,599
that you can definitely see sort of

934
00:37:38,970 --> 00:37:36,819
features associated with anomalous

935
00:37:41,249 --> 00:37:38,980
magnetic field and you see sort of this

936
00:37:43,440 --> 00:37:41,259
loop like structure whereas this is pure

937
00:37:46,230 --> 00:37:43,450
anomalous magnetic field and is

938
00:37:48,089 --> 00:37:46,240

protected from solar winds so very low

939
00:37:50,039 --> 00:37:48,099
solar wind down sitting at higher itís

940
00:37:52,349 --> 00:37:50,049
great density in those regions and then

941
00:37:54,019 --> 00:37:52,359
there's this region down here where the

942
00:37:57,390 --> 00:37:54,029
interplanetary magnetic fields are

943
00:37:59,279 --> 00:37:57,400
connects to the anomalous magnetic field

944
00:38:01,109 --> 00:37:59,289
and almost sort of funnels solar wind

945
00:38:03,180 --> 00:38:01,119
into that region so you see higher

946
00:38:05,069 --> 00:38:03,190
densities here at solar wind and in that

947
00:38:07,380 --> 00:38:05,079
region you're a sitter essentially

948
00:38:09,690 --> 00:38:07,390
seeing where the ionosphere or the

949
00:38:12,150 --> 00:38:09,700
atmosphere of Mars has been eroded or

950
00:38:16,019 --> 00:38:12,160
eaten away by this increased solar win

951
00:38:17,819 --> 00:38:16,029
access so when I went through engine

952
00:38:20,099 --> 00:38:17,829
higher-resolution simulations i found

953
00:38:21,720 --> 00:38:20,109
this is these are itís very loss rates

954
00:38:23,880 --> 00:38:21,730
of the different components both o 2

955
00:38:26,039 --> 00:38:23,890
plus and hydrogen and then solar wind

956
00:38:28,769 --> 00:38:26,049
precipitation rates for nominal

957
00:38:31,499 --> 00:38:28,779
conditions but different orientations of

958
00:38:33,539 --> 00:38:31,509
the strongest anomalies ones where they

959
00:38:35,190 --> 00:38:33,549
were located on the dawn Terminator or

960
00:38:36,130 --> 00:38:35,200
if they were located on the dust

961
00:38:38,230 --> 00:38:36,140
Terminator or

962
00:38:41,170 --> 00:38:38,240
located at midnight and now you can see

963
00:38:43,930 --> 00:38:41,180

significant variation with anomaly

964
00:38:45,670 --> 00:38:43,940
located at orientation and these numbers

965
00:38:48,640 --> 00:38:45,680
work out too big for these for these

966
00:38:52,050 --> 00:38:48,650
nominal conditions of about two to three

967
00:38:55,480 --> 00:38:52,060
times ten to the 25 ions per second

968
00:38:57,760 --> 00:38:55,490
correspond to being over 1 billion years

969
00:39:00,910 --> 00:38:57,770
that would be equivalent to 10

970
00:39:03,190 --> 00:39:00,920
centimeters globally of water lost from

971
00:39:04,450 --> 00:39:03,200
Mars for more storm light conditions

972
00:39:07,060 --> 00:39:04,460
which I'm not showing the numbers here

973
00:39:09,220 --> 00:39:07,070
this increases up to about 10 to the 26

974
00:39:10,930 --> 00:39:09,230
ions per second and that will correspond

975
00:39:16,080 --> 00:39:10,940
to over a billion years being able to

976
00:39:21,670 --> 00:39:18,490
so what are these where the conclusions

977
00:39:23,860 --> 00:39:21,680
from my interactions is that that due to

978
00:39:27,240 --> 00:39:23,870
solar wind interactions alone you could

979
00:39:31,150 --> 00:39:27,250
possibly over the lifetime of Mars lost

980
00:39:32,770 --> 00:39:31,160
meters of water to space and it's

981
00:39:34,780 --> 00:39:32,780
important one of the things that's

982
00:39:36,880 --> 00:39:34,790
important for figuring this out is to

983
00:39:38,830 --> 00:39:36,890
try to get some limits on the

984
00:39:40,860 --> 00:39:38,840
composition of the early Martian

985
00:39:43,900 --> 00:39:40,870
atmosphere as we saw the loss rates

986
00:39:48,280 --> 00:39:43,910
correlated fairly heavily with the mass

987
00:39:49,960 --> 00:39:48,290
of that you assume for Mars another

988
00:39:52,270 --> 00:39:49,970

thing anyway so this so that the

989
00:39:54,820 --> 00:39:52,280
composition is quite important another

990
00:39:56,740 --> 00:39:54,830
thing I think is that that when you can

991
00:39:59,800 --> 00:39:56,750
resolve them when you're able to

992
00:40:02,200 --> 00:39:59,810
simulate properly there is a the loss

993
00:40:04,540 --> 00:40:02,210
rates do correlate with the orientation

994
00:40:06,220 --> 00:40:04,550
of the magnetic anomalies so this means

995
00:40:08,650 --> 00:40:06,230
it is really actually you have to pay

996
00:40:10,240 --> 00:40:08,660
attention to blick whaty changes because

997
00:40:11,830 --> 00:40:10,250
there are times when those anomalies may

998
00:40:14,350 --> 00:40:11,840
not face into the solar wind and

999
00:40:16,590 --> 00:40:14,360
therefore they may your loss rates

1000
00:40:28,680 --> 00:40:16,600
during those periods will have changed

1001
00:40:28,690 --> 00:40:34,410
what's what's the curve best estimates

1002
00:40:39,610 --> 00:40:37,840
it probably tens of meters so it's it's

1003
00:40:41,830 --> 00:40:39,620
in the tens of meters that it took them

1004
00:40:45,300 --> 00:40:41,840
lost but nobody knows how Mr probably

1005
00:40:48,580 --> 00:40:45,310
was because you know so the question is

1006
00:40:50,680 --> 00:40:48,590
was there enough to completely fill that

1007
00:40:52,600 --> 00:40:50,690
northern lowlands some people like James

1008
00:40:55,420 --> 00:40:52,610
head have looked at high resolution

1009
00:40:57,730 --> 00:40:55,430
images and have suggested that that sees

1010
00:41:00,370 --> 00:40:57,740
what he thinks is evidence for seizures

1011
00:41:02,860 --> 00:41:00,380
seashores in wave action around the edge

1012
00:41:04,930 --> 00:41:02,870
of that bull northern lowland so is his

1013
00:41:07,030 --> 00:41:04,940

suggestion is there were times when that

1014
00:41:10,210 --> 00:41:07,040
entire region was filled with a lake a

1015
00:41:12,010 --> 00:41:10,220
giant lake or an ocean but nobody knows

1016
00:41:19,900 --> 00:41:12,020
how much water what you've been moving

1017
00:41:22,600 --> 00:41:19,910
around at the time in a question from

1018
00:41:26,800 --> 00:41:22,610
Penn State for the exceptional school

1019
00:41:28,330 --> 00:41:26,810
yep higher co this Jim casting in the

1020
00:41:31,270 --> 00:41:28,340
beginning when you went through the list

1021
00:41:34,240 --> 00:41:31,280
of escape mechanisms you talked about

1022
00:41:37,180 --> 00:41:34,250
hydrodynamic escape and you mentioned

1023
00:41:39,220 --> 00:41:37,190
that it is non fractionating people who

1024
00:41:41,530 --> 00:41:39,230
suggested that maybe a lot of what we

1025
00:41:43,750 --> 00:41:41,540
associate with being water is actually

1026
00:41:47,050 --> 00:41:43,760
been due to wind or a alone aeolian

1027
00:41:49,570 --> 00:41:47,060
processes and I I don't know if that's

1028
00:41:52,420 --> 00:41:49,580
really how well resolved it is I mean we

1029
00:42:04,309 --> 00:41:52,430
do know that there's water there um so I

1030
00:42:12,150 --> 00:42:09,299
and bandwidth is hit by the evidence is

1031
00:42:14,430 --> 00:42:12,160
not water my teenage colleague at work

1032
00:42:17,279 --> 00:42:14,440
or large patient to visit they see those

1033
00:42:21,630 --> 00:42:17,289
nails over time with your client for

1034
00:42:24,539 --> 00:42:21,640
when I'm slide the spirit caller yeah

1035
00:42:25,829 --> 00:42:24,549
it's not shirring what they are zombie

1036
00:42:28,609 --> 00:42:25,839
I've suggested that there was some sort

1037
00:42:31,439 --> 00:42:28,619
of explosive process that may have

1038
00:42:35,069 --> 00:42:31,449

explosively ice or you know some

1039
00:42:37,650 --> 00:42:35,079
vaporization hey it's yeah it's still

1040
00:42:40,859 --> 00:42:37,660
open for today yeah thank you doing

1041
00:42:49,519 --> 00:42:40,869
something about water could conjure up

1042
00:42:55,049 --> 00:42:52,699
yeah it's not that a lot of the current

1043
00:43:00,209 --> 00:42:55,059
transition or events may be associated

1044
00:43:02,789 --> 00:43:00,219
with impacts of some sort a couple of

1045
00:43:08,099 --> 00:43:02,799
questions for me either so Penn State

1046
00:43:09,299 --> 00:43:08,109
has a question okay sorry Erica win in

1047
00:43:12,209 --> 00:43:09,309
the beginning when you were talking

1048
00:43:15,120 --> 00:43:12,219
about hydrodynamic escape you mentioned

1049
00:43:17,219 --> 00:43:15,130
that it was non fractionating there's

1050
00:43:20,160 --> 00:43:17,229
actually a couple different regimes in

1051
00:43:22,319 --> 00:43:20,170
there but mean what what we call nan

1052
00:43:25,709 --> 00:43:22,329
fractionating escape is often termed

1053
00:43:27,900 --> 00:43:25,719
blow off there's also a regime of

1054
00:43:30,539 --> 00:43:27,910
hydrodynamic escape that that is

1055
00:43:32,640 --> 00:43:30,549
fractionating and there's a long

1056
00:43:39,089 --> 00:43:32,650
literature Bob Pepin has written lots of

1057
00:43:41,430 --> 00:43:39,099
papers on this so so some some loss may

1058
00:43:43,709 --> 00:43:41,440
occur by that mechanism in fact that we

1059
00:43:48,120 --> 00:43:43,719
think that that would be very important

1060
00:43:50,819 --> 00:43:48,130
early on no I thank you for pointing out

1061
00:43:52,769 --> 00:43:50,829
that there are two set two types from

1062
00:43:55,199 --> 00:43:52,779
some of the stuff I've read it suggests

1063
00:43:58,349 --> 00:43:55,209

that also that that some of the early

1064
00:44:00,209 --> 00:43:58,359
mechanisms were more we're not quite as

1065
00:44:02,569 --> 00:44:00,219
mass selective as things that would take

1066
00:44:05,880 --> 00:44:02,579
come over that would have come later on

1067
00:44:08,939 --> 00:44:05,890
but in fact Bob Pepin has derived this

1068
00:44:11,750 --> 00:44:08,949
whole history of the solar system doing

1069
00:44:15,610 --> 00:44:11,760
the fractionation of noble gases and

1070
00:44:19,000 --> 00:44:15,620
gasps isotopes using hydrodynamic escape

1071
00:44:27,710 --> 00:44:19,010
so so that may be part of the picture

1072
00:44:31,760 --> 00:44:27,720
okay thank you any more questions from

1073
00:44:34,100 --> 00:44:31,770
Jim this is dalton can you talk a little

1074
00:44:35,930 --> 00:44:34,110
bit about why I guess certainly just in

1075
00:44:37,940 --> 00:44:35,940
white Venus so has really been

1076
00:44:39,430 --> 00:44:37,950
atmosphere of Mars doesn't if it can you

1077
00:44:44,240 --> 00:44:39,440
say much about the original atmosphere

1078
00:44:45,980 --> 00:44:44,250
Peters has kind of a finish there are a

1079
00:44:47,000 --> 00:44:45,990
couple of things that I don't know a lot

1080
00:44:48,650 --> 00:44:47,010
about Venus but I know there are a

1081
00:44:51,170 --> 00:44:48,660
couple mechanisms that mention Venus

1082
00:44:55,580 --> 00:44:51,180
doesn't have one of these hot oxygen

1083
00:44:57,950 --> 00:44:55,590
type coronas because even after it will

1084
00:45:00,110 --> 00:44:57,960
is the process of photolysis and

1085
00:45:02,630 --> 00:45:00,120
dissociative recombination can occur but

1086
00:45:04,430 --> 00:45:02,640
at Venus the the hot oxygen that is

1087
00:45:07,100 --> 00:45:04,440
created after the dissociative

1088
00:45:09,530 --> 00:45:07,110

recombination is still below escape

1089
00:45:11,810 --> 00:45:09,540
velocity so Venus doesn't have a hot

1090
00:45:13,250 --> 00:45:11,820
oxygen corona so it doesn't have this

1091
00:45:14,870 --> 00:45:13,260
large material it won't have therefore

1092
00:45:17,690 --> 00:45:14,880
it won't have the sputtering and some of

1093
00:45:20,810 --> 00:45:17,700
the pickup processes and so I think

1094
00:45:22,430 --> 00:45:20,820
that's one of the one of the reasons why

1095
00:45:25,280 --> 00:45:22,440
it may have held mine it's also more

1096
00:45:28,010 --> 00:45:25,290
massive so it's escape velocity is a lot

1097
00:45:30,740 --> 00:45:28,020
higher so if I mean you know Congress

1098
00:45:33,380 --> 00:45:30,750
Lee it's also closer to to the Sun but I

1099
00:45:36,230 --> 00:45:33,390
think that the more massive amount more

1100
00:45:42,890 --> 00:45:36,240
more mass does help retain more of the

1101
00:45:46,640 --> 00:45:42,900
atmosphere in that respect any more

1102
00:45:50,160 --> 00:45:46,650
questions comments it's not I'd like to