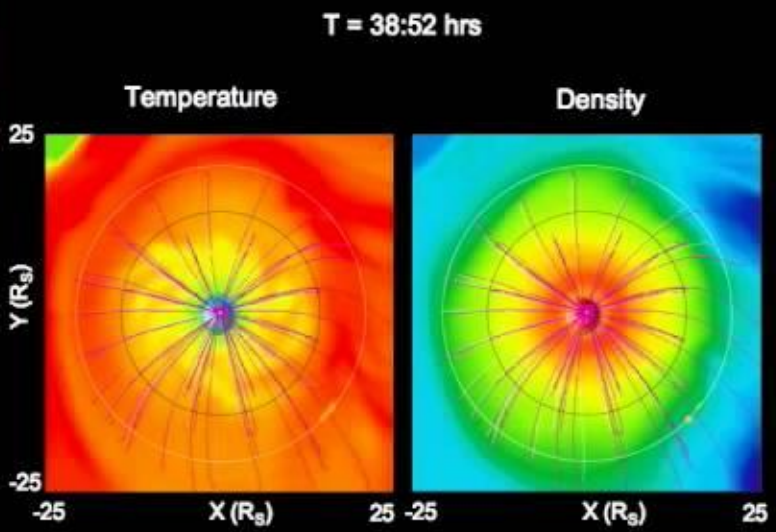
T = 38:52 hrs
Temperature
Density
25
Y (Rs)
-25
-25
X (Rs)
25
-25
X (Rs)
25

1
00:00:05,590 --> 00:00:03,110
today's speaker in the astrobiology

2
00:00:06,789 --> 00:00:05,600
seminar series this quarter is robert

3
00:00:09,350 --> 00:00:06,799
wing lee

4
00:00:10,470 --> 00:00:09,360
he is a graduate of the university of

5
00:00:13,589 --> 00:00:10,480
sydney

6
00:00:15,749 --> 00:00:13,599
in australia not

7
00:00:17,910 --> 00:00:15,759
nova scotia

8
00:00:20,950 --> 00:00:17,920
he got his phd at the university of

9
00:00:23,269 --> 00:00:20,960
sydney in australia not nova scotia

10
00:00:25,590 --> 00:00:23,279
you may think that this is a bit

11
00:00:28,470 --> 00:00:25,600
incestuous and inbred but

12
00:00:29,509 --> 00:00:28,480
this is common in australia i got my phd

13
00:00:30,950 --> 00:00:29,519

from the

14
00:00:33,030 --> 00:00:30,960
same institution that i got my

15
00:00:34,950 --> 00:00:33,040
bachelor's degree

16
00:00:36,950 --> 00:00:34,960
robert is in

17
00:00:38,630 --> 00:00:36,960
earth and space sciences department he's

18
00:00:41,270 --> 00:00:38,640
currently chair

19
00:00:44,069 --> 00:00:41,280
he's in the space physics group with

20
00:00:45,590 --> 00:00:44,079
within earth and space sciences and his

21
00:00:47,830 --> 00:00:45,600
interests are

22
00:00:49,830 --> 00:00:47,840
planetary magnetospheres

23
00:00:52,310 --> 00:00:49,840
and also

24
00:00:55,270 --> 00:00:52,320
exotic and novel and innovative

25
00:00:58,709 --> 00:00:55,280
spacecraft propulsion mechanisms he's

26
00:01:01,029 --> 00:00:58,719
going to talk to us today about um

27
00:01:04,070 --> 00:01:01,039
magnetosphere

28
00:01:06,550 --> 00:01:04,080
effects in the saturn titan system

29
00:01:08,310 --> 00:01:06,560
robert thank you roger yeah so we're

30
00:01:09,270 --> 00:01:08,320
going to talk a little bit about the

31
00:01:11,429 --> 00:01:09,280
saturn

32
00:01:14,230 --> 00:01:11,439
titan system

33
00:01:16,310 --> 00:01:14,240
and while the photos

34
00:01:17,910 --> 00:01:16,320
would typically indicate that these

35
00:01:19,670 --> 00:01:17,920
systems are fairly benign and

36
00:01:21,670 --> 00:01:19,680
non-coupled

37
00:01:23,270 --> 00:01:21,680
they are in fact coupled

38
00:01:24,070 --> 00:01:23,280

due to

39
00:01:30,950 --> 00:01:24,080
the

40
00:01:33,590 --> 00:01:30,960
i'd like to first talk about what satin

41
00:01:35,749 --> 00:01:33,600
looks like and then tap tighten and then

42
00:01:36,789 --> 00:01:35,759
how they become coupled

43
00:01:38,630 --> 00:01:36,799
so

44
00:01:42,230 --> 00:01:38,640
you have satin there

45
00:01:45,350 --> 00:01:42,240
gas giant mainly hydrogen helium

46
00:01:48,389 --> 00:01:45,360
and a little bit of ammonia

47
00:01:49,830 --> 00:01:48,399
uh even ice methane and water ice

48
00:01:51,030 --> 00:01:49,840
present there

49
00:01:53,590 --> 00:01:51,040
and there's some question whether it

50
00:01:55,190 --> 00:01:53,600
actually has a rocky core or not but

51
00:01:58,789 --> 00:01:55,200
potential he

52
00:02:00,389 --> 00:01:58,799
potentially has a rocky core

53
00:02:03,270 --> 00:02:00,399
very cold

54
00:02:05,270 --> 00:02:03,280
it also has a magnetic field

55
00:02:06,709 --> 00:02:05,280
and that sets up

56
00:02:09,109 --> 00:02:06,719
aurora so if you actually peek on the

57
00:02:10,790 --> 00:02:09,119
bottom side of satin

58
00:02:13,910 --> 00:02:10,800
you would actually see

59
00:02:16,309 --> 00:02:13,920
that it has aurora this much similar to

60
00:02:17,510 --> 00:02:16,319
our earth's terrestrial aurora

61
00:02:19,510 --> 00:02:17,520
present

62
00:02:23,190 --> 00:02:19,520
and this arises because of its magnetic

63
00:02:25,510 --> 00:02:23,200

field which then we can sort of uh and

64
00:02:28,390 --> 00:02:25,520
then when it interacts well it's ionized

65
00:02:30,630 --> 00:02:28,400
partly by solar uv coming in

66
00:02:32,630 --> 00:02:30,640
also by the precipitation of energetic

67
00:02:35,110 --> 00:02:32,640
particles which then go to making the

68
00:02:36,390 --> 00:02:35,120
aurora so what we have here is not just

69
00:02:38,550 --> 00:02:36,400
the planet

70
00:02:40,550 --> 00:02:38,560
and its rings but there's a whole lot of

71
00:02:42,710 --> 00:02:40,560
material sitting out here that is

72
00:02:46,309 --> 00:02:42,720
invisible to white light

73
00:02:49,990 --> 00:02:46,319
and it is this uh system that sets up a

74
00:02:52,710 --> 00:02:50,000
magnetosphere and we're interested in

75
00:02:55,990 --> 00:02:52,720
these kinds of processes because aurora

76
00:02:58,229 --> 00:02:56,000
actually provide remote sensing for the

77
00:03:01,270 --> 00:02:58,239
planetary body so

78
00:03:02,949 --> 00:03:01,280
this acts like a phosphor screen so far

79
00:03:05,509 --> 00:03:02,959
as it tells us what's actually out here

80
00:03:07,750 --> 00:03:05,519
in space but it also tells us something

81
00:03:09,589 --> 00:03:07,760
about what's actually at the planet

82
00:03:10,470 --> 00:03:09,599
through the uv emissions so if you could

83
00:03:13,270 --> 00:03:10,480
actually

84
00:03:14,710 --> 00:03:13,280
uh do spectral resolution on those

85
00:03:16,470 --> 00:03:14,720
aurora you'd actually know something

86
00:03:18,470 --> 00:03:16,480
about the material app up in the upper

87
00:03:20,630 --> 00:03:18,480
atmosphere so it's a means of remote

88
00:03:23,110 --> 00:03:20,640

sensing

89
00:03:24,229 --> 00:03:23,120
the magnetosphere itself looks something

90
00:03:26,390 --> 00:03:24,239
like

91
00:03:30,390 --> 00:03:26,400
this so here's satin again

92
00:03:33,910 --> 00:03:30,400
with its rings it has its magnetic field

93
00:03:35,110 --> 00:03:33,920
uh present and

94
00:03:39,670 --> 00:03:35,120
uh

95
00:03:42,149 --> 00:03:39,680
is aligned with the rotational axis but

96
00:03:43,670 --> 00:03:42,159
the rotational axis and is tilted

97
00:03:47,589 --> 00:03:43,680
towards the solar wind so actually the

98
00:03:50,309 --> 00:03:47,599
solar wind is coming in and this the

99
00:03:52,309 --> 00:03:50,319
satin here is a little bit tilted so

100
00:03:53,830 --> 00:03:52,319
actually the bottom side

101
00:03:57,190 --> 00:03:53,840
has in this figure here a little bit

102
00:03:59,509 --> 00:03:57,200
better access to the solar wind than the

103
00:04:01,429 --> 00:03:59,519
northern hemisphere

104
00:04:03,509 --> 00:04:01,439
and what happens here is that these are

105
00:04:05,910 --> 00:04:03,519
charged particles coming in they see the

106
00:04:08,229 --> 00:04:05,920
influence of the magnetic field causes

107
00:04:10,149 --> 00:04:08,239
it to become compressed

108
00:04:12,229 --> 00:04:10,159
on the

109
00:04:15,750 --> 00:04:12,239
day side or the side facing the sun and

110
00:04:17,909 --> 00:04:15,760
we have this elongated magneto tail uh

111
00:04:19,909 --> 00:04:17,919
stretching out here so that's our

112
00:04:22,469 --> 00:04:19,919
magnetosphere and again we talked about

113
00:04:25,749 --> 00:04:22,479

the aurora being present

114
00:04:27,430 --> 00:04:25,759
now little titan is sitting

115
00:04:29,189 --> 00:04:27,440
out here at 20

116
00:04:31,110 --> 00:04:29,199
uh

117
00:04:33,189 --> 00:04:31,120
saturnian radii

118
00:04:36,150 --> 00:04:33,199
where one saturnian rate is about 60 000

119
00:04:38,870 --> 00:04:36,160
kilometers and it sits just about inside

120
00:04:40,790 --> 00:04:38,880
the magnetosphere just at the very edge

121
00:04:44,070 --> 00:04:40,800
of this system here

122
00:04:46,390 --> 00:04:44,080
and so saturn is rotating

123
00:04:47,510 --> 00:04:46,400
at about 10.6 hours so it's sweeping

124
00:04:50,230 --> 00:04:47,520
plasma

125
00:04:52,950 --> 00:04:50,240
around and into titan

126
00:04:54,469 --> 00:04:52,960
so this little titan sitting there

127
00:04:56,070 --> 00:04:54,479
it's the uh

128
00:04:58,310 --> 00:04:56,080
we're interested in it is the second

129
00:05:01,430 --> 00:04:58,320
largest moon and solar system

130
00:05:04,870 --> 00:05:01,440
one of three or depending on how you

131
00:05:07,590 --> 00:05:04,880
count it with thick atmosphere

132
00:05:08,950 --> 00:05:07,600
and that's where the original interest

133
00:05:11,590 --> 00:05:08,960
for titan

134
00:05:13,110 --> 00:05:11,600
was that it had a composition that was

135
00:05:15,510 --> 00:05:13,120
different from sentence and in fact

136
00:05:18,390 --> 00:05:15,520
something that looked presumably like

137
00:05:21,110 --> 00:05:18,400
the uh primeval or the first atmosphere

138
00:05:24,790 --> 00:05:21,120

of our earth

139
00:05:25,990 --> 00:05:24,800
so it has roughly 90 percent nitrogen

140
00:05:27,590 --> 00:05:26,000
pressure

141
00:05:32,150 --> 00:05:27,600
uh ten percent

142
00:05:36,950 --> 00:05:34,310
uh like i said this is presumed to be

143
00:05:38,390 --> 00:05:36,960
very close to our our atmosphere

144
00:05:42,070 --> 00:05:38,400
pressure is actually similar to our

145
00:05:44,070 --> 00:05:42,080
earth atmosphere a little bit larger

146
00:05:46,230 --> 00:05:44,080
it has a rocky interior

147
00:05:47,110 --> 00:05:46,240
silicates present

148
00:05:48,870 --> 00:05:47,120
uh

149
00:05:51,350 --> 00:05:48,880
as well

150
00:05:53,110 --> 00:05:51,360
as water ice the main difference between

151
00:05:54,550 --> 00:05:53,120
this system and our earth is of course

152
00:05:56,870 --> 00:05:54,560
the temperature

153
00:05:58,469 --> 00:05:56,880
where it's exceptionally cold

154
00:06:00,950 --> 00:05:58,479
and instead of having

155
00:06:05,590 --> 00:06:00,960
lakes of

156
00:06:07,670 --> 00:06:05,600
presumably ethane and methane so this is

157
00:06:10,390 --> 00:06:07,680
one of the latest pictures from the

158
00:06:11,830 --> 00:06:10,400
cassini mission where these areas here

159
00:06:13,270 --> 00:06:11,840
are thought to be

160
00:06:15,909 --> 00:06:13,280
uh lakes

161
00:06:16,950 --> 00:06:15,919
of ethanol methane so they're smooth

162
00:06:20,230 --> 00:06:16,960
different

163
00:06:22,469 --> 00:06:20,240

reflectivity

164
00:06:24,390 --> 00:06:22,479
than the other surface material so

165
00:06:26,309 --> 00:06:24,400
that's where it was originally became

166
00:06:30,550 --> 00:06:26,319
of interest did you just point out this

167
00:06:30,560 --> 00:06:33,430
this lineage

168
00:06:37,990 --> 00:06:36,309
so at titan it's a little guy so even

169
00:06:40,150 --> 00:06:38,000
though it's one of the biggest

170
00:06:44,150 --> 00:06:40,160
uh moons uh it's

171
00:06:46,309 --> 00:06:44,160
2500 2600 kilometers a radius

172
00:06:49,029 --> 00:06:46,319
so it's actually fairly large if you put

173
00:06:50,790 --> 00:06:49,039
it to our earth our earth is six

174
00:06:53,110 --> 00:06:50,800
thousand three hundred and seventy so

175
00:06:55,990 --> 00:06:53,120
kilometers so it's a fair size of the

176
00:07:00,309 --> 00:06:57,909
it's thick atmosphere

177
00:07:02,469 --> 00:07:00,319
uh is subject to ionization so it has a

178
00:07:04,550 --> 00:07:02,479
charge layer around it it has no

179
00:07:05,270 --> 00:07:04,560
intrinsic magnetic field

180
00:07:07,350 --> 00:07:05,280
but

181
00:07:08,629 --> 00:07:07,360
the the magnetic field from saturn

182
00:07:10,629 --> 00:07:08,639
sweets by

183
00:07:11,510 --> 00:07:10,639
associated with it so the blue lines

184
00:07:12,790 --> 00:07:11,520
here

185
00:07:14,710 --> 00:07:12,800
uh

186
00:07:17,749 --> 00:07:14,720
actually got this yeah our magnetic

187
00:07:19,670 --> 00:07:17,759
field lines from saturn they come in

188
00:07:22,070 --> 00:07:19,680

they see a conductor they bend around it

189
00:07:24,390 --> 00:07:22,080
to produce this comet like

190
00:07:26,629 --> 00:07:24,400
kind of feature and the plasma flow

191
00:07:29,029 --> 00:07:26,639
comes in and around and bends and you

192
00:07:30,629 --> 00:07:29,039
have charged particles gyrating about

193
00:07:32,870 --> 00:07:30,639
these magnetic fields

194
00:07:35,589 --> 00:07:32,880
so you have a difference in plasma

195
00:07:37,670 --> 00:07:35,599
uh you have hydrogen

196
00:07:40,469 --> 00:07:37,680
maybe some

197
00:07:43,110 --> 00:07:40,479
light ions like uh

198
00:07:45,510 --> 00:07:43,120
nitrogen or oxygen coming in

199
00:07:47,430 --> 00:07:45,520
you may have a series of different kinds

200
00:07:48,230 --> 00:07:47,440
of heavy ions coming

201
00:07:50,710 --> 00:07:48,240
out

202
00:07:53,189 --> 00:07:50,720
of titan so you have the opportunity to

203
00:07:54,550 --> 00:07:53,199
see different ions which again gives you

204
00:07:56,629 --> 00:07:54,560
a chance to

205
00:07:57,749 --> 00:07:56,639
provide remote sensing

206
00:08:00,309 --> 00:07:57,759
you know

207
00:08:03,110 --> 00:08:00,319
speeds of the plasma coming in here are

208
00:08:04,629 --> 00:08:03,120
about 130 kilometers coming in

209
00:08:06,869 --> 00:08:04,639
uh which is slower than the solar wind

210
00:08:08,150 --> 00:08:06,879
which is about 400 or so kilometers per

211
00:08:10,469 --> 00:08:08,160
second

212
00:08:13,189 --> 00:08:10,479
we're talking about

213
00:08:16,230 --> 00:08:13,199

magnetic filters mildly weak

214
00:08:18,230 --> 00:08:16,240
but still philly enough to produce some

215
00:08:20,710 --> 00:08:18,240
strong

216
00:08:22,950 --> 00:08:20,720
modification of the system and we have

217
00:08:25,510 --> 00:08:22,960
coming into

218
00:08:28,150 --> 00:08:25,520
titan about 10 or 25 10 or 26 ions per

219
00:08:29,670 --> 00:08:28,160
second moving into that system you

220
00:08:32,389 --> 00:08:29,680
should remind us how many nano tesla the

221
00:08:34,550 --> 00:08:32,399
earth's field is uh 30 000 nano teslas

222
00:08:36,550 --> 00:08:34,560
so it's one ten thousandths of the

223
00:08:37,750 --> 00:08:36,560
terrestrial magnetic field

224
00:08:40,230 --> 00:08:37,760
so even though it's small well the

225
00:08:42,630 --> 00:08:40,240
demonstrator actually has uh substantial

226
00:08:44,710 --> 00:08:42,640
impact for how titan and saturn couple

227
00:08:45,590 --> 00:08:44,720
together how big

228
00:08:47,190 --> 00:08:45,600
it is

229
00:08:49,269 --> 00:08:47,200
uh

230
00:08:50,949 --> 00:08:49,279
i've forgotten it exactly that much it's

231
00:08:52,710 --> 00:08:50,959
uh a few

232
00:08:54,630 --> 00:08:52,720
i think it's almost i think it's

233
00:08:59,269 --> 00:08:54,640
terrestrial terrestrial-like isn't it

234
00:09:03,590 --> 00:09:02,070
and i always forgot to to mention that a

235
00:09:06,310 --> 00:09:03,600
lot of this work is done in

236
00:09:09,350 --> 00:09:06,320
collaboration with darcy snowden who is

237
00:09:11,190 --> 00:09:09,360
working on titan aria who was working on

238
00:09:13,269 --> 00:09:11,200

the saturn system we got to do my

239
00:09:15,910 --> 00:09:13,279
acknowledgments at the beginning

240
00:09:17,030 --> 00:09:15,920
saturn is also very interesting

241
00:09:18,790 --> 00:09:17,040
because

242
00:09:20,310 --> 00:09:18,800
it has another source of plasma

243
00:09:23,190 --> 00:09:20,320
enceladus

244
00:09:27,110 --> 00:09:23,200
which is um

245
00:09:30,790 --> 00:09:28,230
titan

246
00:09:35,269 --> 00:09:30,800
it has these cracks and it's

247
00:09:38,630 --> 00:09:35,279
recently believed to have uh

248
00:09:41,990 --> 00:09:38,640
uh plumes of gas coming off the southern

249
00:09:44,230 --> 00:09:42,000
hemisphere through cryovolcanism and so

250
00:09:46,710 --> 00:09:44,240
this is thought to be actually one of

251
00:09:48,870 --> 00:09:46,720
the significant sources of of plasma so

252
00:09:51,829 --> 00:09:48,880
it comes out as neutrals coming out of

253
00:09:53,430 --> 00:09:51,839
the volcano but is eventually ionized

254
00:09:56,150 --> 00:09:53,440
through some of the plasma circulating

255
00:09:58,949 --> 00:09:56,160
along and this guy here

256
00:10:01,269 --> 00:09:58,959
is then feeding plasma into the system

257
00:10:03,910 --> 00:10:01,279
and this guy is feeding a different set

258
00:10:05,829 --> 00:10:03,920
of ions into the system it's feeding in

259
00:10:07,910 --> 00:10:05,839
primarily water group

260
00:10:11,269 --> 00:10:07,920
ions into the system so if you could

261
00:10:12,230 --> 00:10:11,279
again image or pick up the uv

262
00:10:14,150 --> 00:10:12,240
uh

263
00:10:16,230 --> 00:10:14,160

from these ionization processes you'd

264
00:10:18,790 --> 00:10:16,240
have a chance to remote sense the

265
00:10:21,350 --> 00:10:18,800
different uh planets or moons around

266
00:10:23,030 --> 00:10:21,360
these systems

267
00:10:24,230 --> 00:10:23,040
so we have to include that that source

268
00:10:25,829 --> 00:10:24,240
as well

269
00:10:29,350 --> 00:10:25,839
so here's a sort of a cartoon it's

270
00:10:33,430 --> 00:10:29,360
believed that the enceladus

271
00:10:36,150 --> 00:10:33,440
uh volcanoes are driven by tidal heating

272
00:10:39,190 --> 00:10:36,160
you have some some inner core here which

273
00:10:43,269 --> 00:10:41,269
causes some of the ice to melt here

274
00:10:45,670 --> 00:10:43,279
breaks through the crack

275
00:10:47,590 --> 00:10:45,680
and again we're talking

276
00:10:49,670 --> 00:10:47,600
just above freezing here

277
00:10:52,310 --> 00:10:49,680
at small very slow temperatures and then

278
00:10:54,389 --> 00:10:52,320
comes out as h2 water vapor and ice

279
00:10:55,750 --> 00:10:54,399
particles moving out

280
00:10:57,030 --> 00:10:55,760
into it

281
00:10:57,910 --> 00:10:57,040
although i don't know whether they've

282
00:10:59,829 --> 00:10:57,920
actually

283
00:11:02,470 --> 00:10:59,839
determined why it's coming out of the

284
00:11:05,269 --> 00:11:02,480
south pole yet but

285
00:11:10,069 --> 00:11:05,279
still a very interesting system

286
00:11:13,590 --> 00:11:11,590
some other applications or what we're

287
00:11:15,990 --> 00:11:13,600
going to look at if you look at some of

288
00:11:19,350 --> 00:11:16,000

the extra solar planets you you know you

289
00:11:21,030 --> 00:11:19,360
have solar-like stars here and then what

290
00:11:24,710 --> 00:11:21,040
you you're typically seeing is

291
00:11:28,630 --> 00:11:24,720
jovian-like planets uh closer in to less

292
00:11:31,190 --> 00:11:28,640
than an iu or so

293
00:11:33,910 --> 00:11:31,200
if you were to

294
00:11:36,150 --> 00:11:33,920
look at the ratios of the systems

295
00:11:39,670 --> 00:11:36,160
for example here's our planetary 60

296
00:11:41,350 --> 00:11:39,680
system of 60 000 kilometers

297
00:11:43,150 --> 00:11:41,360
and you have

298
00:11:47,190 --> 00:11:43,160
your titan of

299
00:11:50,150 --> 00:11:47,200
2575 kilometers the ratio between the

300
00:11:52,790 --> 00:11:50,160
the planet and the moon is about 23 to 1

301
00:11:54,949 --> 00:11:52,800
and our orbital position is at about 20

302
00:11:57,350 --> 00:11:54,959
uh saturnian radii

303
00:11:59,430 --> 00:11:57,360
so if i take a typical star let's call

304
00:12:02,230 --> 00:11:59,440
it 700 kilometers or so

305
00:12:05,509 --> 00:12:02,240
it'd be our extra uh solar planet then

306
00:12:08,230 --> 00:12:05,519
if it's jobin-like call it uh jovian so

307
00:12:10,230 --> 00:12:08,240
70 000 kilometers so the ratio of your

308
00:12:12,629 --> 00:12:10,240
star to the planet here would be about

309
00:12:13,509 --> 00:12:12,639
10 to 1. so this ratio here

310
00:12:17,190 --> 00:12:13,519
is

311
00:12:18,710 --> 00:12:17,200
convert your

312
00:12:21,110 --> 00:12:18,720
au

313
00:12:22,150 --> 00:12:21,120

into planetary

314
00:12:24,870 --> 00:12:22,160
solar

315
00:12:26,389 --> 00:12:24,880
or stellar radii you're about 20. so

316
00:12:28,310 --> 00:12:26,399
in fact you could actually

317
00:12:31,030 --> 00:12:28,320
say that the scaling between

318
00:12:33,509 --> 00:12:31,040
the saturnian system is very much

319
00:12:35,430 --> 00:12:33,519
similar to uh

320
00:12:36,790 --> 00:12:35,440
the extrasolar systems where you have

321
00:12:40,150 --> 00:12:36,800
these kinds

322
00:12:43,030 --> 00:12:40,160
of ratios and distance scales

323
00:12:47,990 --> 00:12:45,590
um we actually have another analog in

324
00:12:51,590 --> 00:12:48,000
our own system the jovian system

325
00:12:53,509 --> 00:12:51,600
uh 70 000 kilometers if we take io

326
00:12:55,350 --> 00:12:53,519
which is smaller radius at one eighteen

327
00:12:57,190 --> 00:12:55,360
hundred kilometers

328
00:12:59,430 --> 00:12:57,200
uh but the ratio of

329
00:13:01,670 --> 00:12:59,440
jupiter to io is about thirty nine to

330
00:13:05,030 --> 00:13:01,680
one all the distances about six much

331
00:13:08,150 --> 00:13:05,040
slightly closer in go to ganymede uh two

332
00:13:10,870 --> 00:13:08,160
thousand 2 630 kilometers your ratio is

333
00:13:13,030 --> 00:13:10,880
26 to 1 and your orbital parameter is

334
00:13:15,030 --> 00:13:13,040
15. so

335
00:13:16,790 --> 00:13:15,040
there are very similar systems moving

336
00:13:19,509 --> 00:13:16,800
out ganymede of course is different from

337
00:13:21,190 --> 00:13:19,519
titan in that it has a magnetic field to

338
00:13:23,990 --> 00:13:21,200

to play around with but again you can

339
00:13:26,790 --> 00:13:24,000
sort of see that there's a sort of

340
00:13:30,470 --> 00:13:26,800
similarity between the ratio

341
00:13:34,870 --> 00:13:32,550
there is an example up here

342
00:13:37,509 --> 00:13:34,880
that's allegedly associated one of these

343
00:13:39,430 --> 00:13:37,519
extrasolar planets uh they've

344
00:13:42,150 --> 00:13:39,440
claimed to have indicated that there's a

345
00:13:44,710 --> 00:13:42,160
sunspot or brightening on the solar so

346
00:13:47,190 --> 00:13:44,720
the plants the stellar surface

347
00:13:50,150 --> 00:13:47,200
associated with the rotation of the

348
00:13:51,990 --> 00:13:50,160
orbital body so even at these ratios

349
00:13:54,389 --> 00:13:52,000
there is some indication that there can

350
00:13:56,870 --> 00:13:54,399
be feedback between

351
00:13:58,710 --> 00:13:56,880
the big guy and a little

352
00:14:00,150 --> 00:13:58,720
oh god whether that's a

353
00:14:02,470 --> 00:14:00,160
solid planet or whether it's a moon

354
00:14:05,750 --> 00:14:02,480
around a gas giant so there are these

355
00:14:08,790 --> 00:14:05,760
analog processes that could be occurring

356
00:14:10,230 --> 00:14:08,800
at the extra solar system

357
00:14:11,110 --> 00:14:10,240
systems

358
00:14:13,670 --> 00:14:11,120
and

359
00:14:16,629 --> 00:14:13,680
ganymede is a more famous

360
00:14:19,829 --> 00:14:16,639
example of this alleged coupling

361
00:14:20,949 --> 00:14:19,839
here so here's jupiter here's a close-up

362
00:14:23,110 --> 00:14:20,959
of

363
00:14:26,150 --> 00:14:23,120

its aurora

364
00:14:28,389 --> 00:14:26,160
and so what they see are three so this

365
00:14:30,230 --> 00:14:28,399
is the auroral pattern going off

366
00:14:31,509 --> 00:14:30,240
and you'll see these three other spots

367
00:14:32,710 --> 00:14:31,519
here one

368
00:14:33,670 --> 00:14:32,720
two

369
00:14:34,470 --> 00:14:33,680
three

370
00:14:36,949 --> 00:14:34,480
this

371
00:14:39,910 --> 00:14:36,959
is believed to be io's footpoint

372
00:14:41,509 --> 00:14:39,920
europa and ganometes footpoint so that

373
00:14:42,949 --> 00:14:41,519
the moons here

374
00:14:45,670 --> 00:14:42,959
at jupiter

375
00:14:47,430 --> 00:14:45,680
are actually talking to the jupiter

376
00:14:49,910 --> 00:14:47,440
jupiter modifying this plasma

377
00:14:51,829 --> 00:14:49,920
environment so again you have some means

378
00:14:52,550 --> 00:14:51,839
of remote sensing here

379
00:14:55,110 --> 00:14:52,560
so

380
00:14:57,350 --> 00:14:55,120
again the the idea is that these moons

381
00:14:59,269 --> 00:14:57,360
are moving through the magnetic field of

382
00:15:01,750 --> 00:14:59,279
jupiter

383
00:15:03,509 --> 00:15:01,760
modifying its magnetic field

384
00:15:05,590 --> 00:15:03,519
moving around these these field lines

385
00:15:08,230 --> 00:15:05,600
that map into jupiter's

386
00:15:10,829 --> 00:15:08,240
high latitude regions causing

387
00:15:14,870 --> 00:15:13,990
emissions and it's unclear whether

388
00:15:16,230 --> 00:15:14,880

uh

389
00:15:19,030 --> 00:15:16,240
kaliso

390
00:15:20,870 --> 00:15:19,040
has a footprint because it's right in

391
00:15:22,710 --> 00:15:20,880
the auroral oval and so they've not been

392
00:15:25,990 --> 00:15:22,720
able to distinguish a separate

393
00:15:27,910 --> 00:15:26,000
kalisto signature

394
00:15:29,990 --> 00:15:27,920
so in these things this is a nice pretty

395
00:15:31,030 --> 00:15:30,000
picture that we're headed towards

396
00:15:35,189 --> 00:15:31,040
is

397
00:15:38,150 --> 00:15:35,199
they can actually see here

398
00:15:39,829 --> 00:15:38,160
at the auroral oval

399
00:15:42,790 --> 00:15:39,839
with the local

400
00:15:45,350 --> 00:15:42,800
sensory measurements

401
00:15:48,230 --> 00:15:45,360
uh by galileo for example we know that

402
00:15:51,030 --> 00:15:48,240
plasma is being stripped off these moons

403
00:15:53,269 --> 00:15:51,040
uh moving up the field line and

404
00:15:56,230 --> 00:15:53,279
communicating energetic particles into

405
00:15:58,069 --> 00:15:56,240
the auroral regions to produce this kind

406
00:15:59,269 --> 00:15:58,079
of coupled systems between the two of

407
00:16:01,749 --> 00:15:59,279
them

408
00:16:04,150 --> 00:16:01,759
so our job what we started to do

409
00:16:05,430 --> 00:16:04,160
was ask the question whether the same

410
00:16:06,829 --> 00:16:05,440
kind

411
00:16:09,030 --> 00:16:06,839
of plasma

412
00:16:11,189 --> 00:16:09,040
interaction occurs

413
00:16:13,749 --> 00:16:11,199

at titan

414
00:16:16,550 --> 00:16:13,759
and how does that go towards stripping

415
00:16:20,150 --> 00:16:16,560
whether we can see relative signatures

416
00:16:23,590 --> 00:16:20,160
of what's happening at titan and versus

417
00:16:25,670 --> 00:16:23,600
saturn now saturn is is weaker

418
00:16:29,269 --> 00:16:25,680
than jupiter and

419
00:16:31,430 --> 00:16:29,279
titan is further out to play around with

420
00:16:34,230 --> 00:16:31,440
now the the this problem is quite a

421
00:16:37,430 --> 00:16:34,240
difficult problem because we've got two

422
00:16:40,069 --> 00:16:37,440
major scale sizes to worry about

423
00:16:41,430 --> 00:16:40,079
so we have saturn sitting at 60 000

424
00:16:43,670 --> 00:16:41,440
kilometers

425
00:16:46,629 --> 00:16:43,680
and we have titan sitting at two and a

426
00:16:48,550 --> 00:16:46,639
half thousand kilometers and your first

427
00:16:50,949 --> 00:16:48,560
guess is boy that's a teensy-weensy

428
00:16:52,629 --> 00:16:50,959
little object go to draw it on the scale

429
00:16:55,350 --> 00:16:52,639
he'd probably be less than this laser

430
00:16:59,189 --> 00:16:55,360
pointer so how can this little guy

431
00:17:00,949 --> 00:16:59,199
have a major effect on this big guy

432
00:17:03,509 --> 00:17:00,959
that's one of the first assumptions that

433
00:17:04,390 --> 00:17:03,519
most people make and this is why we're

434
00:17:08,069 --> 00:17:04,400
actually

435
00:17:09,669 --> 00:17:08,079
out whether that assumption is really

436
00:17:11,909 --> 00:17:09,679
valid

437
00:17:14,549 --> 00:17:11,919
so we've got very big disparity in scale

438
00:17:16,870 --> 00:17:14,559

sizes to play around with

439
00:17:19,110 --> 00:17:16,880
saturn system is complicated because it

440
00:17:20,390 --> 00:17:19,120
has plasmas leaking out from its high

441
00:17:22,949 --> 00:17:20,400
latitudes which would be called the

442
00:17:25,750 --> 00:17:22,959
ionospheric plasma moving out

443
00:17:27,189 --> 00:17:25,760
we have water group ions coming out from

444
00:17:29,590 --> 00:17:27,199
enceladus

445
00:17:31,430 --> 00:17:29,600
we've got time making plasma and we've

446
00:17:33,270 --> 00:17:31,440
got the solar wind plasma coming in here

447
00:17:37,190 --> 00:17:33,280
so you've got a whole lot of different

448
00:17:41,510 --> 00:17:39,430
the solar wind plasma conditions out

449
00:17:43,029 --> 00:17:41,520
there is about 0.05 particles per cubic

450
00:17:45,190 --> 00:17:43,039
centimeter

451
00:17:47,990 --> 00:17:45,200
400 kilometers per second

452
00:17:50,390 --> 00:17:48,000
solar wind speed and about half a nano

453
00:17:52,789 --> 00:17:50,400
tesla coming in here from the solar wind

454
00:17:55,750 --> 00:17:52,799
so again very weak field compared to

455
00:18:00,950 --> 00:17:58,470
titan here then it has its own set of

456
00:18:02,789 --> 00:18:00,960
plasma sources the ammonia group methane

457
00:18:05,750 --> 00:18:02,799
and ethane coming off it and the

458
00:18:07,510 --> 00:18:05,760
incident flow coming in here from titan

459
00:18:11,510 --> 00:18:07,520
has about three astronomical units so

460
00:18:13,510 --> 00:18:11,520
it's a mixture of protons and oxygen uh

461
00:18:15,270 --> 00:18:13,520
ions coming in that speed is actually

462
00:18:18,470 --> 00:18:15,280
slower than the solar wind

463
00:18:20,470 --> 00:18:18,480

carrying about three or so nanoteslas of

464
00:18:22,549 --> 00:18:20,480
magnetic field into titan and its

465
00:18:23,909 --> 00:18:22,559
incident flux there's a couple of orders

466
00:18:24,789 --> 00:18:23,919
of magnitude

467
00:18:27,669 --> 00:18:24,799
down

468
00:18:30,870 --> 00:18:27,679
from what saturn is seeing

469
00:18:34,549 --> 00:18:33,270
so how do we couple how do we solve this

470
00:18:37,110 --> 00:18:34,559
problem

471
00:18:40,549 --> 00:18:37,120
so we're a bunch of modelers

472
00:18:43,190 --> 00:18:40,559
uh we run the fluid equations

473
00:18:44,470 --> 00:18:43,200
which i'm not going to show

474
00:18:46,230 --> 00:18:44,480
uh but we're going to discuss the

475
00:18:49,270 --> 00:18:46,240
gridding system so standard thing is you

476
00:18:51,270 --> 00:18:49,280
would put in a gridding system with ever

477
00:18:53,270 --> 00:18:51,280
increasing grid spacing moving out so

478
00:18:55,350 --> 00:18:53,280
that we cover a very large

479
00:18:57,830 --> 00:18:55,360
uh system size so the satin

480
00:18:59,190 --> 00:18:57,840
magnetosphere extends out a couple of

481
00:19:02,070 --> 00:18:59,200
hundred

482
00:19:03,990 --> 00:19:02,080
saturnian radii so it's quite large

483
00:19:05,909 --> 00:19:04,000
uh

484
00:19:08,549 --> 00:19:05,919
in fact bigger than the sun in total

485
00:19:10,390 --> 00:19:08,559
number of kilometers

486
00:19:12,310 --> 00:19:10,400
in both so we've got a three-dimensional

487
00:19:14,470 --> 00:19:12,320
one this is just a cut

488
00:19:18,070 --> 00:19:14,480

x and y for example

489
00:19:20,390 --> 00:19:18,080
and so we have down to a quarter

490
00:19:21,430 --> 00:19:20,400
planetary radio resolution down around

491
00:19:23,430 --> 00:19:21,440
saturn

492
00:19:25,750 --> 00:19:23,440
moving out

493
00:19:28,870 --> 00:19:25,760
and then what we do for titan is we now

494
00:19:31,510 --> 00:19:28,880
put in an additional set of grid points

495
00:19:34,230 --> 00:19:31,520
around titan to keep going down in

496
00:19:37,110 --> 00:19:34,240
resolution again several several times

497
00:19:38,390 --> 00:19:37,120
down to 100 kilometers so we're actually

498
00:19:40,870 --> 00:19:38,400
able to

499
00:19:43,909 --> 00:19:40,880
view both the small scale and the big

500
00:19:45,190 --> 00:19:43,919
scale systems here

501
00:19:47,430 --> 00:19:45,200
so that's what we're doing and then we

502
00:19:48,710 --> 00:19:47,440
run them

503
00:19:51,350 --> 00:19:48,720
now

504
00:19:52,710 --> 00:19:51,360
with such small scale sizes it's hard to

505
00:19:54,710 --> 00:19:52,720
run a code unless you've got a really

506
00:19:57,350 --> 00:19:54,720
whopping great big code

507
00:19:59,350 --> 00:19:57,360
to process everything so what we do is

508
00:20:01,430 --> 00:19:59,360
we use this grid system

509
00:20:03,270 --> 00:20:01,440
to set up an overall equilibrium it

510
00:20:05,750 --> 00:20:03,280
takes saturn

511
00:20:07,669 --> 00:20:05,760
several tens of hours to come into

512
00:20:09,990 --> 00:20:07,679
equilibrium with solar wind conditions

513
00:20:12,230 --> 00:20:10,000

after that equilibrium is established we

514
00:20:14,870 --> 00:20:12,240
then place in a high resolution grid

515
00:20:19,590 --> 00:20:14,880
around titan and see how that evolves

516
00:20:24,470 --> 00:20:23,590
okay so um here's the uh parameters just

517
00:20:27,270 --> 00:20:24,480
uh

518
00:20:28,789 --> 00:20:27,280
again so a quarter planetary radius down

519
00:20:31,190 --> 00:20:28,799
to all the way down to 100 kilometer

520
00:20:32,470 --> 00:20:31,200
resolution or a fraction of a time

521
00:20:34,950 --> 00:20:32,480
radius

522
00:20:36,230 --> 00:20:34,960
with these species uh

523
00:20:39,190 --> 00:20:36,240
around

524
00:20:41,669 --> 00:20:39,200
titan and these other species here

525
00:20:44,710 --> 00:20:41,679
uh around the inner boundary so we put

526
00:20:46,230 --> 00:20:44,720
in a lump of a torus of plasma

527
00:20:48,390 --> 00:20:46,240
uh around

528
00:20:51,430 --> 00:20:48,400
uh the latitudes of that insulators are

529
00:20:52,230 --> 00:20:51,440
moving around to give its density

530
00:20:56,310 --> 00:20:52,240
there

531
00:20:59,110 --> 00:20:57,510
okay

532
00:21:01,430 --> 00:20:59,120
so that's our system

533
00:21:03,990 --> 00:21:01,440
so here's the uh

534
00:21:06,070 --> 00:21:04,000
look at what happens with saturn's

535
00:21:07,990 --> 00:21:06,080
system when it's just

536
00:21:09,350 --> 00:21:08,000
um

537
00:21:11,029 --> 00:21:09,360
where the planetary magnetic

538
00:21:13,190 --> 00:21:11,039

interplanetary magnetic field is

539
00:21:14,549 --> 00:21:13,200
parallel to saturn's magnetic field all

540
00:21:17,190 --> 00:21:14,559
right so here's a complicated looking

541
00:21:19,350 --> 00:21:17,200
figure

542
00:21:21,110 --> 00:21:19,360
so here's satin now we don't go all the

543
00:21:23,029 --> 00:21:21,120
way into satin radiator so this is our

544
00:21:23,750 --> 00:21:23,039
inner boundary here which is actually

545
00:21:25,909 --> 00:21:23,760
two

546
00:21:27,669 --> 00:21:25,919
saturnian radii not one so just for

547
00:21:29,750 --> 00:21:27,679
scale sizes remember this is two setting

548
00:21:31,590 --> 00:21:29,760
radii not one

549
00:21:32,470 --> 00:21:31,600
we have a cut here

550
00:21:43,190 --> 00:21:32,480
in

551
00:21:45,350 --> 00:21:43,200
of

552
00:21:47,029 --> 00:21:45,360
uh 25

553
00:21:49,990 --> 00:21:47,039
saturnian radius

554
00:21:53,190 --> 00:21:50,000
and this little guy here is titan

555
00:21:54,789 --> 00:21:53,200
so he's just a little little guy here

556
00:21:57,190 --> 00:21:54,799
color contours

557
00:21:59,510 --> 00:21:57,200
are of the solar wind density coming

558
00:22:00,310 --> 00:21:59,520
into the system

559
00:22:02,230 --> 00:22:00,320
so

560
00:22:04,549 --> 00:22:02,240
it piles up on the stronger magnetic

561
00:22:06,710 --> 00:22:04,559
field to produce this round feature

562
00:22:08,710 --> 00:22:06,720
called the magneto pause and then some

563
00:22:10,070 --> 00:22:08,720

of it's allowed to flow into the on the

564
00:22:12,710 --> 00:22:10,080
magnetic field into what's called the

565
00:22:14,549 --> 00:22:12,720
cut so here's a cusp here's another cast

566
00:22:16,549 --> 00:22:14,559
solar wind is coming in this direction

567
00:22:19,430 --> 00:22:16,559
here uh so our

568
00:22:21,190 --> 00:22:19,440
reference frame is such that the uh

569
00:22:22,870 --> 00:22:21,200
rotational plane

570
00:22:24,470 --> 00:22:22,880
of saturn is

571
00:22:25,830 --> 00:22:24,480
in the parallel to the z direction so

572
00:22:29,029 --> 00:22:25,840
the solvents coming at an angle so this

573
00:22:31,830 --> 00:22:29,039
cut here is more intense than this cut

574
00:22:32,789 --> 00:22:31,840
and over here is just the density in per

575
00:22:34,950 --> 00:22:32,799
cubic

576
00:22:37,190 --> 00:22:34,960
centimeters okay

577
00:22:39,750 --> 00:22:37,200
and these guys here are the magnetic

578
00:22:41,590 --> 00:22:39,760
field lines

579
00:22:43,110 --> 00:22:41,600
that trace into the high latitude

580
00:22:44,149 --> 00:22:43,120
regions

581
00:22:45,510 --> 00:22:44,159
for

582
00:22:46,710 --> 00:22:45,520
saturn

583
00:22:48,549 --> 00:22:46,720
okay

584
00:22:49,830 --> 00:22:48,559
and we've led this coming to equilibrium

585
00:22:51,110 --> 00:22:49,840
so we're looking

586
00:22:54,390 --> 00:22:51,120
now

587
00:22:56,789 --> 00:22:54,400
38 hours after we've been blowing in

588
00:22:59,430 --> 00:22:56,799

and then we've started off with zero

589
00:23:02,950 --> 00:22:59,440
interplanetary magnetic field and at

590
00:23:04,630 --> 00:23:02,960
about 34 or so the change in

591
00:23:06,230 --> 00:23:04,640
interplanetary magnetic field has just

592
00:23:08,390 --> 00:23:06,240
started to arrive and soaking in and

593
00:23:10,230 --> 00:23:08,400
this is when we put uh start the run on

594
00:23:12,149 --> 00:23:10,240
titan so here's little titan

595
00:23:13,990 --> 00:23:12,159
it's got its little plasma source that

596
00:23:17,350 --> 00:23:14,000
you can barely see here

597
00:23:19,270 --> 00:23:17,360
but as we let titan evolve

598
00:23:21,590 --> 00:23:19,280
you'll see

599
00:23:23,350 --> 00:23:21,600
it produce a little

600
00:23:24,870 --> 00:23:23,360
tail here

601
00:23:26,230 --> 00:23:24,880
and

602
00:23:28,149 --> 00:23:26,240
a bit of luck

603
00:23:31,110 --> 00:23:28,159
you can actually see a little bit of

604
00:23:32,470 --> 00:23:31,120
tail here and actually if you go back

605
00:23:34,230 --> 00:23:32,480
you'll see

606
00:23:37,510 --> 00:23:34,240
that the magnetic field is actually

607
00:23:39,990 --> 00:23:37,520
getting a little bit inflated

608
00:23:42,630 --> 00:23:40,000
as the parallel magnetic field arrives

609
00:23:45,350 --> 00:23:42,640
so the solar wind is actually as small

610
00:23:48,070 --> 00:23:45,360
as it is is adding flux or magnetic flux

611
00:23:49,350 --> 00:23:48,080
to the entire system and one is able to

612
00:23:51,270 --> 00:23:49,360
start to see

613
00:23:53,590 --> 00:23:51,280

those changes develop

614
00:23:55,190 --> 00:23:53,600
so there's little titan

615
00:23:57,669 --> 00:23:55,200
moving around

616
00:24:00,070 --> 00:23:57,679
um and that's in the light ions protons

617
00:24:01,510 --> 00:24:00,080
if we look

618
00:24:02,630 --> 00:24:01,520
oh there we go and then you can see a

619
00:24:04,789 --> 00:24:02,640
nice little

620
00:24:07,830 --> 00:24:04,799
tail developing here

621
00:24:09,430 --> 00:24:07,840
right and now if you look at it uh this

622
00:24:10,950 --> 00:24:09,440
tail is now getting to be quite long

623
00:24:13,269 --> 00:24:10,960
this is now several

624
00:24:15,590 --> 00:24:13,279
uh saturnian radii

625
00:24:17,190 --> 00:24:15,600
in lamps

626
00:24:19,510 --> 00:24:17,200
make sure i understand you're starting

627
00:24:20,630 --> 00:24:19,520
off with the solar wind

628
00:24:22,390 --> 00:24:20,640
uh just

629
00:24:23,909 --> 00:24:22,400
about to hit it and then you start your

630
00:24:25,430 --> 00:24:23,919
simulation you let the solar wind

631
00:24:27,830 --> 00:24:25,440
particles come in is that what's

632
00:24:29,430 --> 00:24:27,840
changing here uh now actually run the

633
00:24:31,029 --> 00:24:29,440
solid so the solar wind has two

634
00:24:33,350 --> 00:24:31,039
components of the particles and the

635
00:24:36,470 --> 00:24:33,360
interplanetary magnetic field

636
00:24:38,549 --> 00:24:36,480
uh we let the solar wind blow in with

637
00:24:41,029 --> 00:24:38,559
assumed to have zero interplanetary

638
00:24:43,269 --> 00:24:41,039

magnetic field and we let that blow in

639
00:24:44,549 --> 00:24:43,279
for uh about 40 hours to get the

640
00:24:48,310 --> 00:24:44,559
equilibrium

641
00:24:50,470 --> 00:24:48,320
and actually 30 35 or so hours and then

642
00:24:52,149 --> 00:24:50,480
we turn i'll let the interplanetary

643
00:24:53,750 --> 00:24:52,159
magnetic field come into the system and

644
00:24:55,750 --> 00:24:53,760
see how that changes

645
00:24:57,909 --> 00:24:55,760
there's no input from saturn or

646
00:24:59,750 --> 00:24:57,919
enceladus or anything like that

647
00:25:01,430 --> 00:24:59,760
well we have fixed boundary conditions

648
00:25:04,390 --> 00:25:01,440
around here so

649
00:25:07,590 --> 00:25:04,400
uh the as and this is rotating system so

650
00:25:09,909 --> 00:25:07,600
as the magnetosphere uh changes

651
00:25:11,430 --> 00:25:09,919
the you can draw plasma around from the

652
00:25:13,830 --> 00:25:11,440
inner boundary so you can actually pull

653
00:25:15,830 --> 00:25:13,840
plasma around so this is the

654
00:25:17,909 --> 00:25:15,840
extension so we start off with a little

655
00:25:19,269 --> 00:25:17,919
bit of plasma around here and around the

656
00:25:21,510 --> 00:25:19,279
inner boundary

657
00:25:24,230 --> 00:25:21,520
uh this is the planet this is a plasma

658
00:25:26,230 --> 00:25:24,240
disc that forms

659
00:25:27,669 --> 00:25:26,240
uh associated with plasma coming out

660
00:25:29,510 --> 00:25:27,679
from our inner boundaries we end up with

661
00:25:31,190 --> 00:25:29,520
a plasma disc as well

662
00:25:33,430 --> 00:25:31,200
that originated in the solar wind no

663
00:25:35,830 --> 00:25:33,440

that originates from the

664
00:25:38,470 --> 00:25:35,840
from saturn either from enceladus or

665
00:25:39,430 --> 00:25:38,480
from its ionosphere so this plasma is

666
00:25:41,190 --> 00:25:39,440
all

667
00:25:44,310 --> 00:25:41,200
uh

668
00:25:46,390 --> 00:25:44,320
internal source

669
00:25:47,590 --> 00:25:46,400
and most of this plasma so you haven't

670
00:25:49,750 --> 00:25:47,600
talked about though

671
00:25:50,789 --> 00:25:49,760
how you know how much is coming off of

672
00:25:53,190 --> 00:25:50,799
saturn

673
00:25:55,029 --> 00:25:53,200
or you know how do you specify that

674
00:25:57,750 --> 00:25:55,039
source from saturn

675
00:26:00,630 --> 00:25:57,760
in this code um

676
00:26:02,310 --> 00:26:00,640
we we can do that uh in a minute because

677
00:26:04,230 --> 00:26:02,320
we have the beauty about our code is we

678
00:26:05,990 --> 00:26:04,240
have three iron species

679
00:26:10,230 --> 00:26:06,000
we have protons

680
00:26:12,070 --> 00:26:10,240
uh uh cno group and heavy iron group so

681
00:26:14,390 --> 00:26:12,080
in the way the code is

682
00:26:17,909 --> 00:26:14,400
uh protons are allowed to come

683
00:26:20,310 --> 00:26:17,919
from the solar wind or from saturn so

684
00:26:22,710 --> 00:26:20,320
here you see both of these guys and

685
00:26:26,070 --> 00:26:22,720
these guys in a little while i'm going

686
00:26:28,630 --> 00:26:26,080
to show you the density plots

687
00:26:30,390 --> 00:26:28,640
of the water group and the heavies and

688
00:26:31,830 --> 00:26:30,400

they can only come

689
00:26:33,190 --> 00:26:31,840
from either

690
00:26:35,350 --> 00:26:33,200
saturn

691
00:26:37,669 --> 00:26:35,360
or titan they can't come from the solar

692
00:26:39,830 --> 00:26:37,679
wind so there we know that that's the

693
00:26:41,110 --> 00:26:39,840
source of that plasma i'm still missing

694
00:26:44,710 --> 00:26:41,120
how you

695
00:26:47,909 --> 00:26:44,720
you get us

696
00:26:49,830 --> 00:26:47,919
the flux off of saturn is it is it the

697
00:26:52,549 --> 00:26:49,840
electric field it just pulls it off yeah

698
00:26:54,310 --> 00:26:52,559
the electric field pulls it off okay so

699
00:26:56,789 --> 00:26:54,320
you just say that it's there

700
00:26:59,350 --> 00:26:56,799
yep once i get a certain yes so what

701
00:27:01,590 --> 00:26:59,360
happens is you you have these fuel lines

702
00:27:03,190 --> 00:27:01,600
and uh we'll show a little

703
00:27:04,549 --> 00:27:03,200
bit of movies later on but these fuel

704
00:27:06,630 --> 00:27:04,559
lines aren't static they're moving

705
00:27:07,590 --> 00:27:06,640
around so any plasma down here that's

706
00:27:09,830 --> 00:27:07,600
loaded

707
00:27:12,549 --> 00:27:09,840
as these field lines rotate and spin or

708
00:27:14,710 --> 00:27:12,559
change or convect they'll pick up energy

709
00:27:17,430 --> 00:27:14,720
so any plasma starts here will be flung

710
00:27:19,510 --> 00:27:17,440
down to the other field lines and into

711
00:27:22,310 --> 00:27:19,520
the into the disk

712
00:27:23,510 --> 00:27:22,320
they're good questions thank you

713
00:27:25,669 --> 00:27:23,520

all right

714
00:27:26,870 --> 00:27:25,679
so after just four hours here you can

715
00:27:29,110 --> 00:27:26,880
start to see

716
00:27:31,269 --> 00:27:29,120
uh start of a

717
00:27:34,549 --> 00:27:31,279
disc and in fact

718
00:27:35,909 --> 00:27:34,559
uh going back to to to woody's question

719
00:27:37,110 --> 00:27:35,919
here

720
00:27:39,269 --> 00:27:37,120
um

721
00:27:41,029 --> 00:27:39,279
this is just showing you the the heavy

722
00:27:41,830 --> 00:27:41,039
ions here

723
00:27:43,909 --> 00:27:41,840
uh

724
00:27:48,710 --> 00:27:43,919
present here so this is the top view now

725
00:27:49,990 --> 00:27:48,720
and again 25 to 25 rre

726
00:27:51,990 --> 00:27:50,000
rs

727
00:27:53,430 --> 00:27:52,000
this one is density

728
00:27:55,750 --> 00:27:53,440
and this is temperature we've got a

729
00:27:58,710 --> 00:27:55,760
whole lot of hot plasma moving around

730
00:27:59,750 --> 00:27:58,720
you can see that the cold stuff is here

731
00:28:02,710 --> 00:27:59,760
you can actually see a little bit of

732
00:28:04,549 --> 00:28:02,720
spoke like features here but basically

733
00:28:07,830 --> 00:28:04,559
uh you get the hot stuff

734
00:28:08,630 --> 00:28:07,840
just at about titan's orbit coming in

735
00:28:13,830 --> 00:28:08,640
here

736
00:28:15,190 --> 00:28:13,840
all the hot stuff

737
00:28:16,789 --> 00:28:15,200
is i don't have a scale here but this is

738
00:28:18,549 --> 00:28:16,799

more than a kilovolt

739
00:28:20,789 --> 00:28:18,559
in temperature here and then this is

740
00:28:22,789 --> 00:28:20,799
stuff leaking out

741
00:28:24,470 --> 00:28:22,799
across the magnetopores

742
00:28:25,590 --> 00:28:24,480
and again

743
00:28:26,549 --> 00:28:25,600
you'll be able to see a little bit

744
00:28:28,310 --> 00:28:26,559
better

745
00:28:31,510 --> 00:28:28,320
uh the formation

746
00:28:34,310 --> 00:28:31,520
of the little tail that parallel will

747
00:28:36,230 --> 00:28:34,320
tighten this on this white circle here

748
00:28:39,029 --> 00:28:36,240
is if the material

749
00:28:40,070 --> 00:28:39,039
were staying in the same orbit as titan

750
00:28:42,310 --> 00:28:40,080
okay

751
00:28:44,710 --> 00:28:42,320
so we can ask the question whether it's

752
00:28:45,590 --> 00:28:44,720
orbiting or falling in

753
00:28:47,510 --> 00:28:45,600
and

754
00:28:49,909 --> 00:28:47,520
you can see it step out

755
00:28:52,230 --> 00:28:49,919
and you can actually see here that

756
00:28:53,909 --> 00:28:52,240
in fact it's actually falling in

757
00:28:55,909 --> 00:28:53,919
uh

758
00:28:58,470 --> 00:28:55,919
in in towards saturn

759
00:29:00,470 --> 00:28:58,480
this tail coming out and you can see the

760
00:29:02,310 --> 00:29:00,480
hot plasma uh

761
00:29:05,110 --> 00:29:02,320
is now lying at this boundary between

762
00:29:06,470 --> 00:29:05,120
this cold plasma from titan so titanium

763
00:29:07,909 --> 00:29:06,480

is getting a little bit grumpy because

764
00:29:11,269 --> 00:29:07,919
it's being black while this plasma and

765
00:29:15,110 --> 00:29:11,279
it's setting up its reaction back onto

766
00:29:18,710 --> 00:29:16,470
all right

767
00:29:22,070 --> 00:29:18,720
uh the one thing is that this may need a

768
00:29:24,230 --> 00:29:22,080
little tail here is very very

769
00:29:26,310 --> 00:29:24,240
stable here we see it we've lasted four

770
00:29:28,230 --> 00:29:26,320
hours or so and it looks like you know

771
00:29:29,669 --> 00:29:28,240
we don't see any rapid disastrous

772
00:29:31,830 --> 00:29:29,679
changes

773
00:29:33,350 --> 00:29:31,840
actually here we go

774
00:29:34,789 --> 00:29:33,360
okay so that's that's the end of that

775
00:29:37,269 --> 00:29:34,799
run

776
00:29:38,870 --> 00:29:37,279
oh if you wanted to see it in just

777
00:29:40,710 --> 00:29:38,880
uh

778
00:29:42,389 --> 00:29:40,720
an art form

779
00:29:45,029 --> 00:29:42,399
here here's the tail we're playing just

780
00:29:47,750 --> 00:29:45,039
an iso surface of density here these

781
00:29:49,830 --> 00:29:47,760
lines here are flow lines of plasma

782
00:29:52,149 --> 00:29:49,840
streaking around the planet

783
00:29:52,950 --> 00:29:52,159
uh the moon i'm sorry and the red ones

784
00:29:57,029 --> 00:29:52,960
are

785
00:29:59,669 --> 00:29:57,039
moon

786
00:30:01,029 --> 00:29:59,679
and you can see the tail

787
00:30:04,470 --> 00:30:01,039
uh fall

788
00:30:09,510 --> 00:30:04,480

and move out and again here so where

789
00:30:11,669 --> 00:30:09,520
this tail here it is close to ten

790
00:30:15,029 --> 00:30:11,679
saturnian radii long so it's quite a

791
00:30:19,990 --> 00:30:15,039
long tail that is being produced by this

792
00:30:22,549 --> 00:30:21,350
not only is it falling in but it's

793
00:30:24,630 --> 00:30:22,559
actually sinking

794
00:30:27,190 --> 00:30:24,640
a little bit out of the equatorial plane

795
00:30:28,470 --> 00:30:27,200
but the whole point here is it's stable

796
00:30:31,269 --> 00:30:28,480
uh in

797
00:30:33,190 --> 00:30:31,279
position it's with it's quite large when

798
00:30:34,830 --> 00:30:33,200
it's full width if we measure it it's

799
00:30:37,990 --> 00:30:34,840
about a satin

800
00:30:39,990 --> 00:30:38,000
uh radius wide so even though we start

801
00:30:42,950 --> 00:30:40,000
with a very small system it gets kind of

802
00:30:44,870 --> 00:30:42,960
big as it moves in

803
00:30:47,269 --> 00:30:44,880
now saturn is kind of you know it's kind

804
00:30:50,549 --> 00:30:47,279
of a quiet day for saturn while the imf

805
00:30:52,950 --> 00:30:50,559
is is uh parallel to the saturnian

806
00:30:55,190 --> 00:30:52,960
magnetic field titan then

807
00:30:57,510 --> 00:30:55,200
has a little bit of a rough time when we

808
00:30:58,549 --> 00:30:57,520
go and turn the interplanetary magnetic

809
00:31:01,029 --> 00:30:58,559
field

810
00:31:03,110 --> 00:31:01,039
uh anti-parallel to saturn's magnetic

811
00:31:05,350 --> 00:31:03,120
field

812
00:31:07,750 --> 00:31:05,360
and here's a side view and i've

813
00:31:09,669 --> 00:31:07,760

exaggerated uh time a little bit so you

814
00:31:11,990 --> 00:31:09,679
can see what's happening a little bit so

815
00:31:13,990 --> 00:31:12,000
again this is just uh

816
00:31:15,750 --> 00:31:14,000
and this is a projection of its position

817
00:31:17,430 --> 00:31:15,760
uh we've got it at 45 degrees that's a

818
00:31:19,830 --> 00:31:17,440
little bit more closer than the 20

819
00:31:21,510 --> 00:31:19,840
because it's a projection effect okay so

820
00:31:23,029 --> 00:31:21,520
here's the magneto pause

821
00:31:23,990 --> 00:31:23,039
uh

822
00:31:26,549 --> 00:31:24,000
cast

823
00:31:28,630 --> 00:31:26,559
this this feature up here is called the

824
00:31:30,310 --> 00:31:28,640
magnetotail satin

825
00:31:31,909 --> 00:31:30,320
it's at an angle because again the solar

826
00:31:34,470 --> 00:31:31,919
wind is blowing a little bit so you can

827
00:31:37,430 --> 00:31:34,480
actually see sort of a bowl-shaped disk

828
00:31:39,430 --> 00:31:37,440
our earth has got has a flat

829
00:31:41,350 --> 00:31:39,440
uh plasma sheet because it's coming

830
00:31:43,190 --> 00:31:41,360
straight at us

831
00:31:45,029 --> 00:31:43,200
on average

832
00:31:47,269 --> 00:31:45,039
and what happens with

833
00:31:48,950 --> 00:31:47,279
the interplanetary magnetic field as

834
00:31:50,630 --> 00:31:48,960
weak as it is it is adding or

835
00:31:52,630 --> 00:31:50,640
subtracting flux

836
00:31:54,789 --> 00:31:52,640
from the saturnian system so what you're

837
00:31:55,590 --> 00:31:54,799
going to see i hope

838
00:31:57,509 --> 00:31:55,600

is

839
00:31:58,549 --> 00:31:57,519
that as we

840
00:32:01,029 --> 00:31:58,559
start

841
00:32:02,389 --> 00:32:01,039
putting in that antiparallelometic field

842
00:32:06,310 --> 00:32:02,399
that causes

843
00:32:07,029 --> 00:32:06,320
the plasma to convect into the middle of

844
00:32:08,389 --> 00:32:07,039
the

845
00:32:09,990 --> 00:32:08,399
sheet here

846
00:32:11,909 --> 00:32:10,000
but it's because it's a rotating system

847
00:32:14,149 --> 00:32:11,919
as soon as you put more mass into the

848
00:32:17,029 --> 00:32:14,159
system it becomes more influenced by

849
00:32:18,789 --> 00:32:17,039
rotation and so it spins itself out and

850
00:32:22,310 --> 00:32:18,799
so what you're going to see here

851
00:32:24,230 --> 00:32:22,320
is that this feature here

852
00:32:26,230 --> 00:32:24,240
will actually move down so the beginning

853
00:32:28,710 --> 00:32:26,240
of this system plural titan is sort of

854
00:32:31,350 --> 00:32:28,720
sitting on the outside of life

855
00:32:33,029 --> 00:32:31,360
but then during this kind of interaction

856
00:32:35,750 --> 00:32:33,039
it gets totally immersed in a more

857
00:32:37,190 --> 00:32:35,760
hostile environment so hopefully

858
00:32:39,669 --> 00:32:37,200
we click

859
00:32:40,549 --> 00:32:39,679
and click click click

860
00:32:47,029 --> 00:32:40,559
click

861
00:32:50,230 --> 00:32:47,039
being now completely immersed so if i go

862
00:32:52,389 --> 00:32:50,240
backwards in time so right here it's

863
00:32:53,669 --> 00:32:52,399

sitting dead square middle of the plasma

864
00:32:54,950 --> 00:32:53,679
sheet

865
00:32:56,389 --> 00:32:54,960
if we go back

866
00:32:58,789 --> 00:32:56,399
to the beginning

867
00:33:02,710 --> 00:32:58,799
of thai it's actually sitting on the

868
00:33:04,549 --> 00:33:02,720
periphery so during this time

869
00:33:05,830 --> 00:33:04,559
the plasma conditions and in space

870
00:33:07,669 --> 00:33:05,840
environment

871
00:33:09,110 --> 00:33:07,679
around for our little

872
00:33:10,950 --> 00:33:09,120
time

873
00:33:13,110 --> 00:33:10,960
is changing dramatically so it's going

874
00:33:15,110 --> 00:33:13,120
to have a rough time so and also if you

875
00:33:17,669 --> 00:33:15,120
look back if you've got good eyes you'll

876
00:33:19,590 --> 00:33:17,679
see once we turn the ims southward

877
00:33:22,070 --> 00:33:19,600
or anti-parallel i should say

878
00:33:23,909 --> 00:33:22,080
it spins out a little bit

879
00:33:26,230 --> 00:33:23,919
one set spins out it fluffs off some of

880
00:33:27,669 --> 00:33:26,240
the plasma and it shrinks back in a

881
00:33:30,070 --> 00:33:27,679
little bit so there's a there's

882
00:33:31,590 --> 00:33:30,080
certainly the whole system is changing

883
00:33:33,110 --> 00:33:31,600
and you can actually see some material

884
00:33:34,230 --> 00:33:33,120
boiling off

885
00:33:35,509 --> 00:33:34,240
here at

886
00:33:36,830 --> 00:33:35,519
nearly auroral

887
00:33:38,630 --> 00:33:36,840
altitude

888
00:33:40,950 --> 00:33:38,640

latitudes

889
00:33:50,549 --> 00:33:43,029
so

890
00:33:52,789 --> 00:33:50,559
again

891
00:33:54,710 --> 00:33:52,799
this is the cno

892
00:33:56,549 --> 00:33:54,720
group and there's a little titan that

893
00:33:58,149 --> 00:33:56,559
doesn't look like much

894
00:33:59,990 --> 00:33:58,159
on this scale

895
00:34:01,669 --> 00:34:00,000
now what happens with anything that

896
00:34:03,110 --> 00:34:01,679
you're spinning so saturn is spinning

897
00:34:05,509 --> 00:34:03,120
around here

898
00:34:08,069 --> 00:34:05,519
as we put more plasma

899
00:34:09,349 --> 00:34:08,079
into the disk

900
00:34:11,349 --> 00:34:09,359
uh

901
00:34:13,510 --> 00:34:11,359
it becomes unstable

902
00:34:14,950 --> 00:34:13,520
and orion is the one who noted this and

903
00:34:17,270 --> 00:34:14,960
she's writing it up

904
00:34:21,589 --> 00:34:17,280
is that you get these fingers

905
00:34:24,389 --> 00:34:21,599
i'm calling the fingers of death okay

906
00:34:25,270 --> 00:34:24,399
and pour a little tight there right here

907
00:34:27,430 --> 00:34:25,280
and

908
00:34:29,430 --> 00:34:27,440
in fact it's going to get clobbered by

909
00:34:31,349 --> 00:34:29,440
one of these things so if you

910
00:34:32,950 --> 00:34:31,359
watch it rotate around there it goes

911
00:34:36,629 --> 00:34:32,960
gets splattered

912
00:34:38,310 --> 00:34:36,639
by one of those borrowing arches there

913
00:34:40,869 --> 00:34:38,320

and we just turned it off just as the

914
00:34:42,869 --> 00:34:40,879
second one was going to splat into it so

915
00:34:44,550 --> 00:34:42,879
so you can see it running

916
00:34:46,310 --> 00:34:44,560
simply going with saturn's rotation

917
00:34:48,069 --> 00:34:46,320
going with retina's rotation it's

918
00:34:51,109 --> 00:34:48,079
actually slightly dragging so it's not

919
00:34:53,589 --> 00:34:51,119
completely co-rotational but um

920
00:34:55,270 --> 00:34:53,599
it is going around pretty well with it

921
00:34:57,910 --> 00:34:55,280
and so you can see those things and

922
00:34:59,990 --> 00:34:57,920
intensify and get flung

923
00:35:02,230 --> 00:35:00,000
out and you can

924
00:35:04,390 --> 00:35:02,240
see some stuff some stuff going in and

925
00:35:06,310 --> 00:35:04,400
out over here as well as you go

926
00:35:07,190 --> 00:35:06,320
back and forth over this

927
00:35:07,990 --> 00:35:07,200
thing

928
00:35:10,870 --> 00:35:08,000
so

929
00:35:14,069 --> 00:35:10,880
uh time gets splattered here and its

930
00:35:16,230 --> 00:35:14,079
environment becomes different

931
00:35:18,470 --> 00:35:16,240
okay

932
00:35:20,870 --> 00:35:18,480
now titan if you look just down here

933
00:35:23,430 --> 00:35:20,880
titan is kind of pesky it's so you see

934
00:35:26,870 --> 00:35:23,440
this arm coming around

935
00:35:27,750 --> 00:35:26,880
and you actually see it modify

936
00:35:30,069 --> 00:35:27,760
uh

937
00:35:32,069 --> 00:35:30,079
right for example right here you can

938
00:35:33,349 --> 00:35:32,079

actually see it's kind of hole

939
00:35:34,790 --> 00:35:33,359
through that

940
00:35:37,750 --> 00:35:34,800
finger

941
00:35:38,870 --> 00:35:37,760
going to come in it's going to whack it

942
00:35:40,310 --> 00:35:38,880
you can actually see in a couple

943
00:35:42,230 --> 00:35:40,320
occasions here

944
00:35:44,870 --> 00:35:42,240
that there's an indentation

945
00:35:46,310 --> 00:35:44,880
in that one so titan is putting up it's

946
00:35:48,870 --> 00:35:46,320
putting up a fair fight to say it

947
00:35:52,230 --> 00:35:48,880
doesn't want all that plasma um piling

948
00:35:53,750 --> 00:35:52,240
up on it and if we go closer

949
00:35:56,630 --> 00:35:53,760
we can show it a little bit so there's a

950
00:35:58,790 --> 00:35:56,640
little titan here on a zoom up

951
00:36:00,470 --> 00:35:58,800
which we'll see

952
00:36:02,230 --> 00:36:00,480
and here it comes

953
00:36:03,990 --> 00:36:02,240
so it's got its tail

954
00:36:06,230 --> 00:36:04,000
here comes a big finger

955
00:36:08,470 --> 00:36:06,240
coming towards it

956
00:36:10,870 --> 00:36:08,480
and what we see here

957
00:36:12,310 --> 00:36:10,880
is that if you might be able to hint

958
00:36:14,310 --> 00:36:12,320
that there's actually a pile up of

959
00:36:18,230 --> 00:36:14,320
plasma here slightly different color

960
00:36:19,510 --> 00:36:18,240
contour as it piles up

961
00:36:21,270 --> 00:36:19,520
and whoops

962
00:36:22,790 --> 00:36:21,280
and as you see it comes around here

963
00:36:25,109 --> 00:36:22,800

you'll see that that tail gets

964
00:36:27,270 --> 00:36:25,119
completely pushed aside and some of this

965
00:36:29,750 --> 00:36:27,280
plasma actually hooks around

966
00:36:31,430 --> 00:36:29,760
so that titan is now actually completely

967
00:36:34,390 --> 00:36:31,440
distorting

968
00:36:37,349 --> 00:36:34,400
uh the flow of saturn's plasma

969
00:36:39,349 --> 00:36:37,359
around the system here

970
00:36:41,510 --> 00:36:39,359
and then it goes away

971
00:36:44,069 --> 00:36:41,520
like a flag post you can see it

972
00:36:45,750 --> 00:36:44,079
moving away and it tries to recover to

973
00:36:47,589 --> 00:36:45,760
its original position

974
00:36:50,069 --> 00:36:47,599
uh during the density minimum but then

975
00:36:51,990 --> 00:36:50,079
another cloud comes through

976
00:36:54,310 --> 00:36:52,000
so this is sort of a summary is it had a

977
00:36:56,870 --> 00:36:54,320
nice pretty tail

978
00:36:58,470 --> 00:36:56,880
then one of the fingers come around

979
00:36:59,829 --> 00:36:58,480
crush it

980
00:37:01,270 --> 00:36:59,839
the uh

981
00:37:03,349 --> 00:37:01,280
finger is distorted you can see a

982
00:37:05,750 --> 00:37:03,359
minimum in the the density as it plows

983
00:37:07,750 --> 00:37:05,760
in the titan and the tail is also

984
00:37:09,190 --> 00:37:07,760
completely distorted and you can see now

985
00:37:12,470 --> 00:37:09,200
instead of even being closely to

986
00:37:14,870 --> 00:37:12,480
co-rotational it's completely pulled in

987
00:37:16,310 --> 00:37:14,880
so in this particular case

988
00:37:18,710 --> 00:37:16,320

titan's

989
00:37:20,550 --> 00:37:18,720
plasma environment is not stable that

990
00:37:23,750 --> 00:37:20,560
it's its tail can actually be totally

991
00:37:27,510 --> 00:37:25,510
all right

992
00:37:29,430 --> 00:37:27,520
now this takes quite a bit of art form

993
00:37:31,990 --> 00:37:29,440
to get used to this plot

994
00:37:35,670 --> 00:37:33,349
and we did a little

995
00:37:36,390 --> 00:37:35,680
bit crazy with the purples here

996
00:37:39,349 --> 00:37:36,400
okay

997
00:37:41,190 --> 00:37:39,359
so this is a top view of titan so we're

998
00:37:42,710 --> 00:37:41,200
just going to focus down so now we've

999
00:37:44,390 --> 00:37:42,720
dropped our resolution

1000
00:37:46,870 --> 00:37:44,400
to a couple

1001
00:37:49,750 --> 00:37:46,880
of saturnian radii

1002
00:37:52,150 --> 00:37:49,760
so this is a top view

1003
00:37:54,710 --> 00:37:52,160
of the system that we sort of saw before

1004
00:37:57,190 --> 00:37:54,720
and this is a vertical view

1005
00:37:58,790 --> 00:37:57,200
so this is looking the z direction but

1006
00:38:00,150 --> 00:37:58,800
because stuff

1007
00:38:02,870 --> 00:38:00,160
is flowing

1008
00:38:04,790 --> 00:38:02,880
in on average this direction

1009
00:38:06,230 --> 00:38:04,800
we've got three planes cutting it here

1010
00:38:08,790 --> 00:38:06,240
here and here so these are these three

1011
00:38:09,910 --> 00:38:08,800
planes okay and again we're only looking

1012
00:38:13,910 --> 00:38:09,920
at a few

1013
00:38:15,030 --> 00:38:13,920

uh solar saturnian radii

1014
00:38:16,470 --> 00:38:15,040
and the question that we're trying to

1015
00:38:17,750 --> 00:38:16,480
answer by looking at this card is not

1016
00:38:20,630 --> 00:38:17,760
only how long is this tail which we've

1017
00:38:23,030 --> 00:38:20,640
already seen but what is the up down

1018
00:38:24,950 --> 00:38:23,040
extent how big is that

1019
00:38:26,950 --> 00:38:24,960
and so here we go

1020
00:38:28,470 --> 00:38:26,960
uh into it so and this middle panel of

1021
00:38:30,470 --> 00:38:28,480
course you'll be kind of picking out

1022
00:38:35,030 --> 00:38:30,480
there as you did this is quite an

1023
00:38:37,349 --> 00:38:35,040
excellent piece of work here it goes

1024
00:38:40,230 --> 00:38:37,359
so you can see the tail punching out to

1025
00:38:42,470 --> 00:38:40,240
here this is the extension of that tail

1026
00:38:44,710 --> 00:38:42,480
in there

1027
00:38:46,630 --> 00:38:44,720
and

1028
00:38:49,349 --> 00:38:46,640
we've got it just uh here comes one of

1029
00:38:52,390 --> 00:38:49,359
the fingers in high resolution

1030
00:38:53,270 --> 00:38:52,400
um so fairly uniform here just hasn't

1031
00:38:54,870 --> 00:38:53,280
that it

1032
00:38:56,630 --> 00:38:54,880
quite got to tighten

1033
00:38:57,910 --> 00:38:56,640
and you can actually see this stripe and

1034
00:38:59,750 --> 00:38:57,920
the density

1035
00:39:00,870 --> 00:38:59,760
here extending

1036
00:39:02,630 --> 00:39:00,880
several

1037
00:39:04,790 --> 00:39:02,640
uh solar radii

1038
00:39:08,470 --> 00:39:04,800

up this is the magnetic field being hung

1039
00:39:09,510 --> 00:39:08,480
up on titan not being able to

1040
00:39:11,270 --> 00:39:09,520
twist

1041
00:39:16,150 --> 00:39:11,280
and so you can see it as a very

1042
00:39:23,190 --> 00:39:18,710
puts up at impacts

1043
00:39:26,790 --> 00:39:24,790
and i'll go through it quickly again

1044
00:39:31,270 --> 00:39:26,800
here's the thing of whopping into it you

1045
00:39:35,430 --> 00:39:33,190
bite out in the density

1046
00:39:37,270 --> 00:39:35,440
going through

1047
00:39:39,109 --> 00:39:37,280
and then you can see

1048
00:39:41,190 --> 00:39:39,119
recovering its tail and coming back let

1049
00:39:43,270 --> 00:39:41,200
me go back

1050
00:39:45,190 --> 00:39:43,280
so you can see this thing is there it's

1051
00:39:47,589 --> 00:39:45,200
certainly moving around

1052
00:39:49,030 --> 00:39:47,599
but certainly a a present feature for a

1053
00:39:50,630 --> 00:39:49,040
very very long time

1054
00:39:53,670 --> 00:39:50,640
the reason that's happening is the

1055
00:39:55,109 --> 00:39:53,680
magnetic field is piling up on this guy

1056
00:39:57,510 --> 00:39:55,119
and that means you have a chance of

1057
00:39:59,589 --> 00:39:57,520
accelerating particles

1058
00:40:02,310 --> 00:39:59,599
making aurora

1059
00:40:04,710 --> 00:40:02,320
modifying the entire

1060
00:40:05,670 --> 00:40:04,720
jovian system in fact and you can also

1061
00:40:07,990 --> 00:40:05,680
see it

1062
00:40:10,310 --> 00:40:08,000
in temperature so this is the ion

1063
00:40:11,910 --> 00:40:10,320

temperature again kilovolts is up here

1064
00:40:13,510 --> 00:40:11,920
so we've got a whole lot of hot plasma

1065
00:40:14,470 --> 00:40:13,520
titan is nice and cold

1066
00:40:16,630 --> 00:40:14,480
stuff

1067
00:40:17,750 --> 00:40:16,640
is coming through

1068
00:40:19,190 --> 00:40:17,760
and

1069
00:40:21,670 --> 00:40:19,200
you can again

1070
00:40:25,109 --> 00:40:21,680
see time making striations

1071
00:40:28,230 --> 00:40:25,119
here in the temperature profile

1072
00:40:29,829 --> 00:40:28,240
and it's still quite persistent in here

1073
00:40:32,470 --> 00:40:29,839
but it's remembering the old plasma

1074
00:40:36,150 --> 00:40:32,480
here's the cold bit plasma spreads up

1075
00:40:39,589 --> 00:40:38,630
and there we go

1076
00:40:41,030 --> 00:40:39,599
so

1077
00:40:42,870 --> 00:40:41,040
for us

1078
00:40:45,109 --> 00:40:42,880
uh who's doing space physics this is

1079
00:40:48,310 --> 00:40:45,119
kind of an important effect because

1080
00:40:49,109 --> 00:40:48,320
at this kind of scale size

1081
00:40:51,349 --> 00:40:49,119
this

1082
00:40:53,750 --> 00:40:51,359
scale size is almost closely

1083
00:40:56,710 --> 00:40:53,760
equivalent to the entire

1084
00:40:58,870 --> 00:40:56,720
width of the plasma sheet of saturn so

1085
00:41:01,349 --> 00:40:58,880
stuff is trying to come in

1086
00:41:04,069 --> 00:41:01,359
trying to make aurora it appears that

1087
00:41:05,990 --> 00:41:04,079
titan may in fact be setting up the

1088
00:41:07,030 --> 00:41:06,000

point when it's in the tail about where

1089
00:41:09,430 --> 00:41:07,040
the inner

1090
00:41:11,829 --> 00:41:09,440
plasma sheet should be which would then

1091
00:41:14,630 --> 00:41:11,839
affect where the aurora might be

1092
00:41:16,309 --> 00:41:14,640
occurring and so this is a fairly strong

1093
00:41:18,870 --> 00:41:16,319
prediction that's being made here about

1094
00:41:21,990 --> 00:41:18,880
its influence when it's in the tail

1095
00:41:23,190 --> 00:41:22,000
because it's certainly modifying it

1096
00:41:25,030 --> 00:41:23,200
and you can see the nice vertical

1097
00:41:27,510 --> 00:41:25,040
stripes here

1098
00:41:29,589 --> 00:41:27,520
so it's it's it's having a big effect

1099
00:41:31,349 --> 00:41:29,599
so summary let me just say that we've

1100
00:41:32,630 --> 00:41:31,359
played around here with saturn's plasma

1101
00:41:34,550 --> 00:41:32,640
environment

1102
00:41:36,309 --> 00:41:34,560
we see that the solar wind and

1103
00:41:37,829 --> 00:41:36,319
interplanetary magnetic field have

1104
00:41:40,390 --> 00:41:37,839
influences

1105
00:41:42,309 --> 00:41:40,400
on the system from the planetary

1106
00:41:44,550 --> 00:41:42,319
magnetic field it couples to the

1107
00:41:46,550 --> 00:41:44,560
planetary magnetic field

1108
00:41:49,750 --> 00:41:46,560
and with its fast rotation sets up by

1109
00:41:51,750 --> 00:41:49,760
magnetosphere which is then

1110
00:41:54,309 --> 00:41:51,760
very quite variable and this means that

1111
00:41:56,390 --> 00:41:54,319
we have a variable plasma environment at

1112
00:41:58,069 --> 00:41:56,400
titan

1113
00:41:59,990 --> 00:41:58,079

this leads to

1114
00:42:02,630 --> 00:42:00,000
induced

1115
00:42:04,710 --> 00:42:02,640
magnetosphere around titan

1116
00:42:06,550 --> 00:42:04,720
but it's

1117
00:42:11,109 --> 00:42:06,560
it certainly leads to enhanced stripping

1118
00:42:16,470 --> 00:42:13,430
it leads to specific ions that we can

1119
00:42:18,309 --> 00:42:16,480
actually track out from titan so that

1120
00:42:20,390 --> 00:42:18,319
you can see

1121
00:42:21,750 --> 00:42:20,400
for example in in our case difference

1122
00:42:23,910 --> 00:42:21,760
between the nitrogen that would be

1123
00:42:26,390 --> 00:42:23,920
coming out from titan versus

1124
00:42:29,109 --> 00:42:26,400
the o plus coming out from enceladus and

1125
00:42:31,750 --> 00:42:29,119
so these definitely mixing of plasmas

1126
00:42:33,190 --> 00:42:31,760
we see that we have an extended tail out

1127
00:42:34,710 --> 00:42:33,200
to at least

1128
00:42:37,030 --> 00:42:34,720
tens of

1129
00:42:38,069 --> 00:42:37,040
saturnian radii but it's certainly

1130
00:42:40,309 --> 00:42:38,079
subject

1131
00:42:43,109 --> 00:42:40,319
to disruption due to changes in the

1132
00:42:46,230 --> 00:42:43,119
solar wind conditions

1133
00:42:47,990 --> 00:42:46,240
uh conversely saturn is able to then

1134
00:42:50,630 --> 00:42:48,000
since it's such a large tail is actually

1135
00:42:52,710 --> 00:42:50,640
modifying saturn's planet uh plasma

1136
00:42:54,390 --> 00:42:52,720
system and so there may in fact be

1137
00:42:56,550 --> 00:42:54,400
really strong two-way coupling which

1138
00:43:03,829 --> 00:42:56,560

we're still continuing to research i'll

1139
00:43:03,839 --> 00:43:08,710
preston

1140
00:43:12,790 --> 00:43:10,550
i've got what

1141
00:43:14,950 --> 00:43:12,800
oh you bring up a very interesting thing

1142
00:43:17,190 --> 00:43:14,960
here at the very end of course uh the

1143
00:43:19,030 --> 00:43:17,200
stripping of the atmosphere and so forth

1144
00:43:20,390 --> 00:43:19,040
you haven't put in any of that coupling

1145
00:43:22,950 --> 00:43:20,400
yet

1146
00:43:24,870 --> 00:43:22,960
is that part of what you plan to do um

1147
00:43:27,030 --> 00:43:24,880
if there's a couple systems now i didn't

1148
00:43:28,150 --> 00:43:27,040
we're still running the numbers because

1149
00:43:30,069 --> 00:43:28,160
uh

1150
00:43:31,270 --> 00:43:30,079
it's highly variable and so we didn't

1151
00:43:34,390 --> 00:43:31,280
realize it was going to be as variable

1152
00:43:38,309 --> 00:43:34,400
but we see nearly an order of magnitude

1153
00:43:40,150 --> 00:43:38,319
change in the outflow of the titan irons

1154
00:43:41,670 --> 00:43:40,160
during some of these events so it's

1155
00:43:42,470 --> 00:43:41,680
oscillating very

1156
00:43:44,950 --> 00:43:42,480
uh

1157
00:43:46,950 --> 00:43:44,960
significantly and we need to plot out

1158
00:43:49,589 --> 00:43:46,960
exactly what that change in flux rate is

1159
00:43:51,750 --> 00:43:49,599
but its orders of magnitude changes

1160
00:43:53,589 --> 00:43:51,760
that'd be extremely interesting to see

1161
00:43:55,510 --> 00:43:53,599
what the time averaged is as well as the

1162
00:43:57,829 --> 00:43:55,520
variability and yeah we haven't gone

1163
00:43:59,270 --> 00:43:57,839

that far yet and obviously the

1164
00:44:00,630 --> 00:43:59,280
atmosphere is there it hasn't been

1165
00:44:01,910 --> 00:44:00,640
stripped so that implies you've got to

1166
00:44:04,470 --> 00:44:01,920
have the input

1167
00:44:05,910 --> 00:44:04,480
yeah i still think uh this is not a real

1168
00:44:09,109 --> 00:44:05,920
fast strip

1169
00:44:10,550 --> 00:44:09,119
stripping mechanism for titan uh i think

1170
00:44:13,270 --> 00:44:10,560
we're losing

1171
00:44:15,990 --> 00:44:13,280
it's it's like a standard type of system

1172
00:44:18,870 --> 00:44:16,000
i think that's uh

1173
00:44:20,630 --> 00:44:18,880
yeah 10 of 25 i think that works out to

1174
00:44:23,270 --> 00:44:20,640
be let's see

1175
00:44:25,349 --> 00:44:23,280
i o is a ton of second i think this is

1176
00:44:27,349 --> 00:44:25,359
only a hundredth of a ton per second or

1177
00:44:28,230 --> 00:44:27,359
something

1178
00:44:29,829 --> 00:44:28,240
can you

1179
00:44:33,750 --> 00:44:29,839
relate that to atmospheres for billion

1180
00:44:38,390 --> 00:44:36,550
i think the answer is uh

1181
00:44:40,870 --> 00:44:38,400
i think the standard answer for most of

1182
00:44:43,190 --> 00:44:40,880
the moon system is of order of a few

1183
00:44:45,589 --> 00:44:43,200
meters per billion years

1184
00:44:47,109 --> 00:44:45,599
that's what we typically strip out

1185
00:44:48,950 --> 00:44:47,119
of ice

1186
00:44:49,829 --> 00:44:48,960
if i had it if i condensed it into ice i

1187
00:44:51,910 --> 00:44:49,839
guess

1188
00:44:53,589 --> 00:44:51,920

solid yeah

1189
00:44:55,109 --> 00:44:53,599
and you guys would have to convert

1190
00:44:59,030 --> 00:44:55,119
solids to gas

1191
00:45:05,589 --> 00:45:01,430
good this is a little bit tangential but

1192
00:45:07,910 --> 00:45:05,599
going back to enceladus yes

1193
00:45:10,230 --> 00:45:07,920
water ions being injected but you also

1194
00:45:13,030 --> 00:45:10,240
mentioned ice particles being ejected

1195
00:45:14,230 --> 00:45:13,040
right what is the nature or fate of

1196
00:45:18,309 --> 00:45:14,240
those

1197
00:45:20,150 --> 00:45:18,319
that particularly does anybody have

1198
00:45:23,190 --> 00:45:20,160
okay carol can do it she's working on

1199
00:45:25,030 --> 00:45:23,200
that um actually the particular icing

1200
00:45:26,470 --> 00:45:25,040
dust is what they believe makes up the

1201
00:45:29,030 --> 00:45:26,480
whole e-brain

1202
00:45:30,870 --> 00:45:29,040
and the e-ring is superposed on the

1203
00:45:33,270 --> 00:45:30,880
solid since orbital location it's

1204
00:45:35,510 --> 00:45:33,280
looking more and more like

1205
00:45:37,829 --> 00:45:35,520
the coincidence is pretty impossible

1206
00:45:42,150 --> 00:45:37,839
like their enceladus is feeding

1207
00:45:52,710 --> 00:45:43,670
which is the most diffuse of the rings

1208
00:45:56,710 --> 00:45:54,550
what is the results of your computer

1209
00:45:58,550 --> 00:45:56,720
modeling compared to what cassini has

1210
00:46:00,710 --> 00:45:58,560
actually measured we're actually doing

1211
00:46:03,349 --> 00:46:00,720
pretty good i think we're the

1212
00:46:04,630 --> 00:46:03,359
the first to actually

1213
00:46:06,870 --> 00:46:04,640

write supposed to be writing this up

1214
00:46:08,390 --> 00:46:06,880
first to identify the source mechanism

1215
00:46:12,230 --> 00:46:08,400
for the fingers

1216
00:46:15,030 --> 00:46:12,240
uh they were observed by cassini and

1217
00:46:16,550 --> 00:46:15,040
were able to start producing that darcy

1218
00:46:21,109 --> 00:46:16,560
has worked up

1219
00:46:23,190 --> 00:46:21,119
uh titans uh close in to titan

1220
00:46:24,710 --> 00:46:23,200
and able to reproduce the magnetic field

1221
00:46:28,150 --> 00:46:24,720
signatures there

1222
00:46:29,910 --> 00:46:28,160
and then this modeling here is then

1223
00:46:34,309 --> 00:46:29,920
providing a link between those two sets

1224
00:46:36,309 --> 00:46:34,319
of observations which you can't really

1225
00:46:38,390 --> 00:46:36,319
do from the very few cassini

1226
00:46:40,829 --> 00:46:38,400
observations so this is providing an

1227
00:46:42,630 --> 00:46:40,839
important link

1228
00:46:44,790 --> 00:46:42,640
the

1229
00:46:47,109 --> 00:46:44,800
just recently a paper was published by

1230
00:46:49,750 --> 00:46:47,119
people at iowa

1231
00:46:50,950 --> 00:46:49,760
indicating that titan is in fact

1232
00:46:52,950 --> 00:46:50,960
um

1233
00:46:55,750 --> 00:46:52,960
modifying the radio emissions from

1234
00:46:57,829 --> 00:46:55,760
saturn they have

1235
00:46:59,270 --> 00:46:57,839
earth and jupiter and saturn are

1236
00:47:01,829 --> 00:46:59,280
actually bright

1237
00:47:03,270 --> 00:47:01,839
broadcasters in the radio

1238
00:47:04,710 --> 00:47:03,280

and in fact can be brighter than the sun

1239
00:47:05,990 --> 00:47:04,720
in the radio

1240
00:47:07,510 --> 00:47:06,000
uh

1241
00:47:10,150 --> 00:47:07,520
at jupiter it's well known that's a lot

1242
00:47:11,349 --> 00:47:10,160
of those radio emissions are modified by

1243
00:47:14,309 --> 00:47:11,359
the moons

1244
00:47:17,910 --> 00:47:14,319
the first result that titan

1245
00:47:19,910 --> 00:47:17,920
is modifying the emissions at saturn has

1246
00:47:22,069 --> 00:47:19,920
only just been published and

1247
00:47:23,910 --> 00:47:22,079
this work here is providing a means to

1248
00:47:26,150 --> 00:47:23,920
explain that coupling which hasn't been

1249
00:47:27,670 --> 00:47:26,160
developed either

1250
00:47:29,270 --> 00:47:27,680
previously

1251
00:47:31,510 --> 00:47:29,280
i could just inject brighter than the

1252
00:47:33,349 --> 00:47:31,520
sun at those low frequencies that does

1253
00:47:34,870 --> 00:47:33,359
low frequencies

1254
00:47:36,150 --> 00:47:34,880
i didn't say that i said at those

1255
00:47:39,190 --> 00:47:36,160
frequencies

1256
00:47:41,510 --> 00:47:39,200
at the radio yeah

1257
00:47:45,990 --> 00:47:41,520
we get to cheat

1258
00:47:50,950 --> 00:47:48,710
i've got one if carl sagan is right or

1259
00:47:53,230 --> 00:47:50,960
was right and there's life on titan how

1260
00:47:56,069 --> 00:47:53,240
is it being affected by the

1261
00:47:59,589 --> 00:47:56,079
magnetosphere and the plasma environment

1262
00:48:01,430 --> 00:47:59,599
around the planet as you've modeled it

1263
00:48:03,910 --> 00:48:01,440

right now

1264
00:48:05,829 --> 00:48:03,920
most of the stuff is low energy sentence

1265
00:48:08,150 --> 00:48:05,839
magnetic field

1266
00:48:09,750 --> 00:48:08,160
is too weak to really get a good

1267
00:48:12,950 --> 00:48:09,760
radiation built

1268
00:48:14,150 --> 00:48:12,960
up at titan so uh

1269
00:48:16,150 --> 00:48:14,160
right now

1270
00:48:17,589 --> 00:48:16,160
those little bugs be nice and happy

1271
00:48:19,829 --> 00:48:17,599
now we have no effect we're just blowing

1272
00:48:21,030 --> 00:48:19,839
off some of the material at the top the

1273
00:48:22,950 --> 00:48:21,040
question is

1274
00:48:24,630 --> 00:48:22,960
what happens when you're

1275
00:48:26,390 --> 00:48:24,640
an extra solar planet if you're going

1276
00:48:28,069 --> 00:48:26,400
hunting for those guys now you're in a

1277
00:48:31,030 --> 00:48:28,079
most hostile

1278
00:48:32,710 --> 00:48:31,040
plasma environment presumably the

1279
00:48:34,710 --> 00:48:32,720
may or may not have stronger magnetic

1280
00:48:36,150 --> 00:48:34,720
field you may have a lot more energetic

1281
00:48:37,589 --> 00:48:36,160
particles and then the little bugs out

1282
00:48:40,390 --> 00:48:37,599
there might have some

1283
00:48:43,670 --> 00:48:40,400
more interesting life

1284
00:48:47,430 --> 00:48:43,680
we do have a question from the outside

1285
00:48:53,270 --> 00:48:49,589
oh yeah i just wonder uh

1286
00:48:55,910 --> 00:48:53,280
what if you put an intrinsic magnetic

1287
00:48:58,549 --> 00:48:55,920
magnetic field on titan and how that

1288
00:49:02,470 --> 00:48:58,559

will affect the mass loss rate will that

1289
00:49:04,710 --> 00:49:02,480
reduce it significantly this is a habit

1290
00:49:06,870 --> 00:49:04,720
oh that's a real good question um

1291
00:49:08,710 --> 00:49:06,880
we've not done that for titan but we've

1292
00:49:10,150 --> 00:49:08,720
done a little bit of exploratory work

1293
00:49:13,829 --> 00:49:10,160
for ganymede which does have an

1294
00:49:18,710 --> 00:49:16,790
there the loss rates are about the same

1295
00:49:20,630 --> 00:49:18,720
but what happens is the energy is

1296
00:49:23,109 --> 00:49:20,640
concentrated into the poles and if you

1297
00:49:27,430 --> 00:49:23,119
look at ganymede for example

1298
00:49:29,190 --> 00:49:27,440
the ice looks uh cleaner

1299
00:49:31,109 --> 00:49:29,200
and the poles and it's dirty in the

1300
00:49:33,349 --> 00:49:31,119
middle which is protected so you get

1301
00:49:34,950 --> 00:49:33,359
faster stripping at the pulse so you

1302
00:49:36,870 --> 00:49:34,960
concentrate your energy into those

1303
00:49:38,630 --> 00:49:36,880
systems

1304
00:49:41,030 --> 00:49:38,640
in a system which also has an intrinsic

1305
00:49:43,030 --> 00:49:41,040
magnetic field you get conversion of

1306
00:49:45,030 --> 00:49:43,040
some of the magnetic energy into

1307
00:49:47,270 --> 00:49:45,040
particle acceleration by a process

1308
00:49:49,349 --> 00:49:47,280
called magnetic reconnection

1309
00:49:51,670 --> 00:49:49,359
so you may have a more

1310
00:49:53,670 --> 00:49:51,680
energetic particle environment than we

1311
00:49:58,069 --> 00:49:53,680
have for this induced

1312
00:49:58,079 --> 00:50:03,430
thank you

1313
00:50:06,630 --> 00:50:04,950

i've got a follow-up question if you

1314
00:50:08,549 --> 00:50:06,640
were to project

1315
00:50:10,470 --> 00:50:08,559
either a few billion years into the

1316
00:50:15,109 --> 00:50:10,480
future or a few billion years into the

1317
00:50:20,710 --> 00:50:17,670
can you speculate about the possible

1318
00:50:22,309 --> 00:50:20,720
history of life on titan as a result of

1319
00:50:23,510 --> 00:50:22,319
its magnetospheric and plasma

1320
00:50:25,349 --> 00:50:23,520
environment

1321
00:50:26,630 --> 00:50:25,359
um

1322
00:50:30,470 --> 00:50:26,640
sorry

1323
00:50:34,470 --> 00:50:32,309
why aren't you asking me about life on i

1324
00:50:37,190 --> 00:50:34,480
know the galilean means rather than time

1325
00:50:39,349 --> 00:50:37,200
time is kind of a cold isn't it so yeah

1326
00:50:42,150 --> 00:50:39,359
but let's say there's a weird life out

1327
00:50:43,349 --> 00:50:42,160
there that can cope with it i mean

1328
00:50:45,109 --> 00:50:43,359
let's say there's

1329
00:50:46,309 --> 00:50:45,119
there's

1330
00:50:49,829 --> 00:50:46,319
you know a

1331
00:50:50,950 --> 00:50:49,839
domain barossa out there

1332
00:50:52,309 --> 00:50:50,960
that

1333
00:51:00,230 --> 00:50:52,319
has

1334
00:51:03,510 --> 00:51:00,240
solvent and lives by converting

1335
00:51:03,520 --> 00:51:10,069
okay i'm not going to answer that one

1336
00:51:13,829 --> 00:51:11,990
well thank you very much robert i should

1337
00:51:16,470 --> 00:51:13,839
before we leave i should mention that

1338
00:51:18,790 --> 00:51:16,480

robert is also director newly installed

1339
00:51:20,870 --> 00:51:18,800
director of the space grant here so if

1340
00:51:22,549 --> 00:51:20,880
anyone wants either some space or a

1341
00:51:25,109 --> 00:51:22,559
grant

1342
00:51:27,430 --> 00:51:25,119
everybody at universities want to

1343
00:51:29,510 --> 00:51:27,440
see robert about and i would put in that

1344
00:51:32,630 --> 00:51:29,520
we have instigated some graduate student

1345
00:51:34,630 --> 00:51:32,640
support uh so if you're out of graduate

1346
00:51:37,910 --> 00:51:34,640
student support even even though ashford

1347
00:51:39,670 --> 00:51:37,920
has more funds than we do not anymore

1348
00:51:41,109 --> 00:51:39,680
there is we have instigated some

1349
00:51:42,390 --> 00:51:41,119
graduate student support as well as