1
00:00:00,160 --> 00:00:09,970
[Music]

2
00:00:15,320 --> 00:00:12,140
hey good evening ladies and gentlemen

3
00:00:16,849 --> 00:00:15,330
how's everyone tonight good well as

4
00:00:19,160 --> 00:00:16,859
always thank you very very much for

5
00:00:21,260 --> 00:00:19,170
coming out to join us Juneau the

6
00:00:23,890 --> 00:00:21,270
solar-powered spacecraft that has been

7
00:00:27,140 --> 00:00:23,900
orbiting Jupiter since July 4th 2016

8
00:00:29,300 --> 00:00:27,150
flies by the giant planet every 53 days

9
00:00:32,269 --> 00:00:29,310
collecting a wealth of new information

10
00:00:34,250 --> 00:00:32,279
with each pass the data collected so far

11
00:00:36,440 --> 00:00:34,260
have revolutionized our understanding of

12
00:00:38,720 --> 00:00:36,450
Jupiter and of giant planets in general

13
00:00:40,819 --> 00:00:38,730

this talk will present some of Juno's

14
00:00:42,819 --> 00:00:40,829
current science results and discuss what

15
00:00:45,590 --> 00:00:42,829
we might expect in the coming years

16
00:00:48,020 --> 00:00:45,600
tonight's guest is the Juno project

17
00:00:50,029 --> 00:00:48,030
scientist and the lead co-investigator

18
00:00:52,040 --> 00:00:50,039
for Juno's microwave radiometer

19
00:00:55,040 --> 00:00:52,050
instrument he has worked at the Jet

20
00:00:57,200 --> 00:00:55,050
Propulsion Laboratory since 1990 during

21
00:00:59,540 --> 00:00:57,210
which time his research interests have

22
00:01:01,430 --> 00:00:59,550
included the light left over from the

23
00:01:04,549 --> 00:01:01,440
Big Bang the search for extraterrestrial

24
00:01:07,010 --> 00:01:04,559
intelligence measuring magnetic fields

25
00:01:09,380 --> 00:01:07,020
in star forming regions looking for

26
00:01:11,300 --> 00:01:09,390
near-earth asteroids and modeling radio

27
00:01:13,969 --> 00:01:11,310
emissions from Jupiter's radiation belts

28
00:01:16,670 --> 00:01:13,979
he is done radio astronomy from large

29
00:01:19,490 --> 00:01:16,680
telescopes mountaintop research stations

30
00:01:22,550 --> 00:01:19,500
the South Pole high-altitude balloons

31
00:01:24,260 --> 00:01:22,560
and of course spacecraft additionally he

32
00:01:26,450 --> 00:01:24,270
is currently the lead scientist for the

33
00:01:28,609 --> 00:01:26,460
Goldstone Apple Valley radio telescope

34
00:01:31,730 --> 00:01:28,619
project in which students learn about

35
00:01:33,410 --> 00:01:31,740
science by doing real science he is also

36
00:01:34,780 --> 00:01:33,420
an elected member of the Board of

37
00:01:36,830 --> 00:01:34,790
Education in Culver City California

38
00:01:38,690 --> 00:01:36,840

where he lives with his wife and three

39
00:01:40,460 --> 00:01:38,700
children ladies and gentlemen please

40
00:01:41,920 --> 00:01:40,470
help me welcome tonight's guest dr.

41
00:01:48,160 --> 00:01:41,930
Steve Levin

42
00:01:56,330 --> 00:01:54,530
hi everybody so as you just heard I'm

43
00:01:59,120 --> 00:01:56,340
gonna talk to you about Gino and what we

44
00:02:01,160 --> 00:01:59,130
learned at Jupiter and I'm probably

45
00:02:02,859 --> 00:02:01,170
gonna try to rush through all the slides

46
00:02:05,390 --> 00:02:02,869
to make sure we have time for questions

47
00:02:09,050 --> 00:02:05,400
at the end because questions are my

48
00:02:13,040 --> 00:02:09,060
favorite part but if I'm going too fast

49
00:02:14,420 --> 00:02:13,050
let me know and save up all your

50
00:02:16,070 --> 00:02:14,430
questions and ask me a ton of questions

51
00:02:19,370 --> 00:02:16,080
at the end because as I said that's the

52
00:02:21,770 --> 00:02:19,380
fun part okay but first let me tell you

53
00:02:23,060 --> 00:02:21,780
a little bit about what Juno is what

54
00:02:25,430 --> 00:02:23,070
we're trying to do so Juno is a

55
00:02:26,990 --> 00:02:25,440
solar-powered spacecraft as you just

56
00:02:32,150 --> 00:02:27,000
heard it's been orbiting at Jupiter

57
00:02:34,250 --> 00:02:32,160
since fourth of July 2016 and we're it's

58
00:02:37,040 --> 00:02:34,260
enough fifty three day orbit so every 53

59
00:02:38,780 --> 00:02:37,050
days we have a close flyby of Jupiter we

60
00:02:42,199 --> 00:02:38,790
get a whole bunch of data for a couple

61
00:02:44,240 --> 00:02:42,209
hours really say eight hours total and

62
00:02:45,860 --> 00:02:44,250
most of the really good stuff is within

63
00:02:48,290 --> 00:02:45,870

a couple hours of our closest approach

64
00:02:49,880 --> 00:02:48,300
then we spend 53 days really far from

65
00:02:52,100 --> 00:02:49,890
the planet come around again

66
00:02:54,170 --> 00:02:52,110
and do it again so we get this big burst

67
00:02:57,229 --> 00:02:54,180
of data every 53 days we've done a dozen

68
00:03:00,430 --> 00:02:57,239
or so of those so far and what we've

69
00:03:04,069 --> 00:03:00,440
learned has been just absolutely amazing

70
00:03:05,720 --> 00:03:04,079
our picture of what Jupiter is like and

71
00:03:07,670 --> 00:03:05,730
what it's made out of and what it looks

72
00:03:10,750 --> 00:03:07,680
like is completely different than it was

73
00:03:13,460 --> 00:03:10,760
before we got there with the spacecraft

74
00:03:15,289 --> 00:03:13,470
so before I tell you all that stuff I

75
00:03:16,759 --> 00:03:15,299
need to talk a little bit about what

76
00:03:18,770 --> 00:03:16,769
we're doing and it's gonna seem like I

77
00:03:21,440 --> 00:03:18,780
take forever on this slide because I do

78
00:03:24,860 --> 00:03:21,450
but don't worry I'll be faster on all

79
00:03:26,479 --> 00:03:24,870
the others alright so there's four main

80
00:03:28,310 --> 00:03:26,489
things we're trying to do at Jupiter

81
00:03:31,759 --> 00:03:28,320
four main science goals we're trying to

82
00:03:33,920 --> 00:03:31,769
understand the origin of Jupiter how did

83
00:03:36,289 --> 00:03:33,930
the giant planet form and that's really

84
00:03:38,050 --> 00:03:36,299
important because if you want to

85
00:03:40,340 --> 00:03:38,060
understand how solar systems form

86
00:03:42,530 --> 00:03:40,350
Jupiter is a really good place to start

87
00:03:44,870 --> 00:03:42,540
if you want to know where the earth came

88
00:03:46,490 --> 00:03:44,880

from where do we come from you need to

89
00:03:49,250 --> 00:03:46,500
understand where Jupiter came from and

90
00:03:51,410 --> 00:03:49,260
the simplest way to understand that to

91
00:03:54,259 --> 00:03:51,420
picture that in your mind is to think

92
00:03:57,500 --> 00:03:54,269
about our solar system and how it formed

93
00:03:58,410 --> 00:03:57,510
and what we know is basically ninety

94
00:04:00,089 --> 00:03:58,420
nine and a half

95
00:04:02,190 --> 00:04:00,099
the mass in the solar system is the Sun

96
00:04:05,250 --> 00:04:02,200
so almost all of it is the Sun in the

97
00:04:07,979 --> 00:04:05,260
Sun form first of that remaining half a

98
00:04:09,660 --> 00:04:07,989
percent or so that's left more than

99
00:04:12,720 --> 00:04:09,670
two-thirds of that is Jupiter and

100
00:04:14,190 --> 00:04:12,730
Jupiter form next all the other planets

101
00:04:16,259 --> 00:04:14,200
and asteroids and comets and all of that

102
00:04:20,400 --> 00:04:16,269
stuff that we see in our solar system

103
00:04:22,290 --> 00:04:20,410
are formed after Jupiter and they're in

104
00:04:24,510 --> 00:04:22,300
that little bit of you know one-third

105
00:04:28,080 --> 00:04:24,520
less than one-third of what's left after

106
00:04:31,320 --> 00:04:28,090
you take out the Sun and Jupiter right

107
00:04:32,850 --> 00:04:31,330
so you can think of it as Jupiter formed

108
00:04:34,560 --> 00:04:32,860
from the leftovers of the Sun and

109
00:04:36,900 --> 00:04:34,570
everything else formed from the

110
00:04:38,580 --> 00:04:36,910
leftovers of Jupiter so if we want to

111
00:04:39,810 --> 00:04:38,590
know how did the solar system form it's

112
00:04:41,640 --> 00:04:39,820
really important to understand how

113
00:04:43,409 --> 00:04:41,650

Jupiter formed and a couple of the

114
00:04:46,020 --> 00:04:43,419
things that we didn't know before Juno

115
00:04:47,670 --> 00:04:46,030
got there that'll really help us are to

116
00:04:50,640 --> 00:04:47,680
understand how much water there is in

117
00:04:52,980 --> 00:04:50,650
Jupiter and to understand the mass of

118
00:04:55,140 --> 00:04:52,990
Jupiter's core down inside Jupiter's a

119
00:04:58,020 --> 00:04:55,150
gas giant so it's made out of mostly

120
00:05:00,480 --> 00:04:58,030
hydrogen and helium just like the Sun

121
00:05:03,420 --> 00:05:00,490
that sort of composition and all the

122
00:05:05,640 --> 00:05:03,430
heavy stuff inside Jupiter tells us

123
00:05:07,350 --> 00:05:05,650
about the origin much of that will have

124
00:05:09,029 --> 00:05:07,360
sunk down into the middle and made a

125
00:05:10,830 --> 00:05:09,039
dense core down in the center of the

126
00:05:14,279 --> 00:05:10,840
planet we needed to know how big that

127
00:05:15,420 --> 00:05:14,289
core was likewise if you look at the

128
00:05:17,250 --> 00:05:15,430
solar system and say what are the

129
00:05:19,140 --> 00:05:17,260
elements what's the solar system made

130
00:05:22,500 --> 00:05:19,150
out of the most abundant element is

131
00:05:24,960 --> 00:05:22,510
hydrogen the next one is helium and the

132
00:05:28,770 --> 00:05:24,970
third one is oxygen so if you think

133
00:05:31,680 --> 00:05:28,780
about it hydrogen is a gas helium is a

134
00:05:34,920 --> 00:05:31,690
gas the first solid you're going to get

135
00:05:36,779 --> 00:05:34,930
is going to be water h2o two hydrogen's

136
00:05:39,029 --> 00:05:36,789
and an oxygen because oxygen is the

137
00:05:41,700 --> 00:05:39,039
third most abundant thing so our

138
00:05:44,430 --> 00:05:41,710

theories of how the planets form revolve

139
00:05:47,790 --> 00:05:44,440
around water we think that Jupiter

140
00:05:50,580 --> 00:05:47,800
probably formed from asteroid sized

141
00:05:52,590 --> 00:05:50,590
pieces of ice colliding together and

142
00:05:54,450 --> 00:05:52,600
sticking till you had enough so that

143
00:05:57,870 --> 00:05:54,460
it's gravity could hold the hydrogen and

144
00:05:59,760 --> 00:05:57,880
helium and make a giant planet if that's

145
00:06:01,920 --> 00:05:59,770
what happened then we should find water

146
00:06:03,750 --> 00:06:01,930
in Jupiter and how much water we find

147
00:06:06,000 --> 00:06:03,760
should tell us whether it worked that

148
00:06:07,740 --> 00:06:06,010
way whether it was smaller pieces of ice

149
00:06:09,730 --> 00:06:07,750
whether it's you put our form far from

150
00:06:11,439 --> 00:06:09,740
the Sun where it's really cold or

151
00:06:14,080 --> 00:06:11,449
or closer to the Sun where it is now

152
00:06:15,939 --> 00:06:14,090
where the the ice water still makes ice

153
00:06:18,100 --> 00:06:15,949
but maybe the the other elements don't

154
00:06:19,809 --> 00:06:18,110
stick to the ice the same way so the

155
00:06:21,760 --> 00:06:19,819
ratio of how much water there is to how

156
00:06:23,710 --> 00:06:21,770
much of the other stuff there is and

157
00:06:25,480 --> 00:06:23,720
tells us a lot about how Jupiter formed

158
00:06:28,180 --> 00:06:25,490
so those are two big things we want to

159
00:06:29,439 --> 00:06:28,190
find the core and the water and then we

160
00:06:31,450 --> 00:06:29,449
want to understand the interior of

161
00:06:34,270 --> 00:06:31,460
Jupiter in general right what we see

162
00:06:36,580 --> 00:06:34,280
from the earth is just clouds in the top

163
00:06:38,379 --> 00:06:36,590

of Jupiter's enormous atmosphere it's

164
00:06:40,240 --> 00:06:38,389
300 times the mass of the earth

165
00:06:43,210 --> 00:06:40,250
it's bigger volume you could fit a

166
00:06:44,920 --> 00:06:43,220
thousand earths inside and we see this

167
00:06:46,570 --> 00:06:44,930
amazing structure that you see in the

168
00:06:49,149 --> 00:06:46,580
pig picture there with belts and zones

169
00:06:51,279 --> 00:06:49,159
those those orange and white stripes

170
00:06:54,460 --> 00:06:51,289
those are jet streams moving at hundreds

171
00:06:57,249 --> 00:06:54,470
of miles an hour we don't see many

172
00:06:59,080 --> 00:06:57,259
throws from the earth until Juno got

173
00:07:01,420 --> 00:06:59,090
there and started doing measurements we

174
00:07:03,040 --> 00:07:01,430
had very little understanding of what

175
00:07:05,339 --> 00:07:03,050
the atmosphere of Jupiter was like

176
00:07:07,510 --> 00:07:05,349
underneath those clouds at the very top

177
00:07:09,909 --> 00:07:07,520
and the planet of course is mostly

178
00:07:11,170 --> 00:07:09,919
atmosphere all right so that's a big

179
00:07:14,890 --> 00:07:11,180
thing we want to understand it to

180
00:07:16,300 --> 00:07:14,900
understand the interior of the planet we

181
00:07:18,010 --> 00:07:16,310
need to understand about the core down

182
00:07:19,719 --> 00:07:18,020
inside we need to understand how deep

183
00:07:22,089 --> 00:07:19,729
those belts and zones go we need to

184
00:07:24,999 --> 00:07:22,099
understand how everything moves interior

185
00:07:27,339 --> 00:07:25,009
to the planet then of course it is giant

186
00:07:29,439 --> 00:07:27,349
gas giant planet we want to understand

187
00:07:31,510 --> 00:07:29,449
its atmosphere it has the Great Red Spot

188
00:07:33,790 --> 00:07:31,520

it has a storm bigger than the entire

189
00:07:35,560 --> 00:07:33,800
earth it has the jet streams that I

190
00:07:37,689 --> 00:07:35,570
mentioned it has all these motions and

191
00:07:39,909 --> 00:07:37,699
all these deep storms that we can learn

192
00:07:41,680 --> 00:07:39,919
about to understand Jupiter and also to

193
00:07:43,600 --> 00:07:41,690
understand about how weather works in

194
00:07:45,490 --> 00:07:43,610
general and maybe even understand about

195
00:07:48,969 --> 00:07:45,500
weather on other planets by having

196
00:07:51,430 --> 00:07:48,979
Jupiter to compare with and finally

197
00:07:53,170 --> 00:07:51,440
because of the orbit we're in our

198
00:07:55,149 --> 00:07:53,180
spacecraft remember I said it starts out

199
00:07:57,129 --> 00:07:55,159
really far away from the planet and it

200
00:07:58,450 --> 00:07:57,139
comes in and it orbits over the poles so

201
00:08:01,659 --> 00:07:58,460
if you watch in that little movie you

202
00:08:05,529 --> 00:08:01,669
see little imaginary spacecraft flying

203
00:08:07,719 --> 00:08:05,539
by what that means is that when it goes

204
00:08:09,459 --> 00:08:07,729
over the pole of Jupiter it's crossing

205
00:08:11,620 --> 00:08:09,469
all the magnetic field lines if you

206
00:08:13,149 --> 00:08:11,630
think of Jupiter's magnetic field like

207
00:08:16,510 --> 00:08:13,159
the Earth's magnetic field shown as

208
00:08:19,810 --> 00:08:16,520
those white lines they're looking curly

209
00:08:21,279 --> 00:08:19,820
here these things should show up yeah

210
00:08:22,230 --> 00:08:21,289
you can barely see the arrow if you're

211
00:08:24,540 --> 00:08:22,240
looking

212
00:08:26,909 --> 00:08:24,550
so if you look at those right as our

213
00:08:28,590 --> 00:08:26,919

spacecraft comes in it crosses all of

214
00:08:30,390 --> 00:08:28,600
those magnetic field lines and that's

215
00:08:32,250 --> 00:08:30,400
important because out away from the

216
00:08:34,409 --> 00:08:32,260
planet there's these giant radiation

217
00:08:36,920 --> 00:08:34,419
belts high-energy particles that can fry

218
00:08:40,290 --> 00:08:36,930
the electronics on a spacecraft that

219
00:08:42,240 --> 00:08:40,300
generate radio waves that produce aurora

220
00:08:44,159 --> 00:08:42,250
Lights in the northern and southern

221
00:08:45,990 --> 00:08:44,169
whites in Jupiter's atmosphere when the

222
00:08:47,910 --> 00:08:46,000
particles hit the atmosphere all of

223
00:08:49,980 --> 00:08:47,920
those particles are arranged by the

224
00:08:51,660 --> 00:08:49,990
magnetic field in general charged

225
00:08:53,460 --> 00:08:51,670
particles spiral around the magnetic

226
00:08:56,310 --> 00:08:53,470
field lines and follow them up and down

227
00:08:58,680 --> 00:08:56,320
so if you measure the particles in one

228
00:09:01,920 --> 00:08:58,690
place on a magnetic field line you're

229
00:09:03,780 --> 00:09:01,930
learning a lot about what they do

230
00:09:05,790 --> 00:09:03,790
everywhere on that same magnetic field

231
00:09:07,769 --> 00:09:05,800
line and because we're coming over the

232
00:09:10,710 --> 00:09:07,779
pole and because the planet is rotating

233
00:09:12,180 --> 00:09:10,720
we cross all the magnetic field lines so

234
00:09:14,610 --> 00:09:12,190
we can measure the particles that hit

235
00:09:18,150 --> 00:09:14,620
the spacecraft and learn about almost

236
00:09:20,340 --> 00:09:18,160
Jupiter's entire magnetosphere as well

237
00:09:22,350 --> 00:09:20,350
by coming over the pole we get the first

238
00:09:24,720 --> 00:09:22,360

good look at the north and south poles

239
00:09:26,790 --> 00:09:24,730
of Jupiter and that includes the Aurora

240
00:09:28,350 --> 00:09:26,800
the the lights as I said that are

241
00:09:30,240 --> 00:09:28,360
generated by particles hitting the upper

242
00:09:31,680 --> 00:09:30,250
atmosphere so we learn about the

243
00:09:34,110 --> 00:09:31,690
magnetosphere that way we learn about

244
00:09:36,120 --> 00:09:34,120
the radiation belts by taking pictures

245
00:09:37,350 --> 00:09:36,130
of the Aurora at the same time as we

246
00:09:39,930 --> 00:09:37,360
measure the particles that are hitting

247
00:09:41,160 --> 00:09:39,940
the spacecraft that will eventually go

248
00:09:43,740 --> 00:09:41,170
down and hit the planet and make the

249
00:09:45,810 --> 00:09:43,750
Aurora okay so we have a great vantage

250
00:09:47,610 --> 00:09:45,820
point to see the magnetosphere we have a

251
00:09:49,829 --> 00:09:47,620
bunch of instruments on board to do that

252
00:09:53,430 --> 00:09:49,839
and I've color-coded them with yellow to

253
00:09:54,540 --> 00:09:53,440
match that yellow text and then as I

254
00:09:58,110 --> 00:09:54,550
said we're trying to understand the

255
00:10:00,630 --> 00:09:58,120
atmosphere we get at the atmosphere in a

256
00:10:02,040 --> 00:10:00,640
number of ways but one of the key ways

257
00:10:05,160 --> 00:10:02,050
that we study the atmosphere of Jupiter

258
00:10:06,960 --> 00:10:05,170
is with the microwave radiometer so what

259
00:10:09,210 --> 00:10:06,970
it's doing is it's using radio waves

260
00:10:11,880 --> 00:10:09,220
because radio can see through the clouds

261
00:10:13,530 --> 00:10:11,890
so we get really close to the planet we

262
00:10:15,840 --> 00:10:13,540
look through the clouds with the radio

263
00:10:17,340 --> 00:10:15,850

waves and for the first time we can see

264
00:10:19,290 --> 00:10:17,350
beneath the clouds and look at you

265
00:10:21,510 --> 00:10:19,300
Pater's atmosphere in the radio so

266
00:10:22,710 --> 00:10:21,520
that's one way of seeing into the planet

267
00:10:26,400 --> 00:10:22,720
a little bit and learn about the

268
00:10:29,550 --> 00:10:26,410
atmosphere it's also how we try to

269
00:10:32,730 --> 00:10:29,560
measure the water because water absorbs

270
00:10:34,290 --> 00:10:32,740
microwaves so the more water there is in

271
00:10:34,770 --> 00:10:34,300
the atmosphere the less we can see

272
00:10:36,870 --> 00:10:34,780
inside

273
00:10:39,090 --> 00:10:36,880
the less water there is the deeper we

274
00:10:40,980 --> 00:10:39,100
can see so by having a bunch of channels

275
00:10:42,600 --> 00:10:40,990
on the radio receiver that see different

276
00:10:44,970 --> 00:10:42,610
depths and measuring how deep they

277
00:10:46,170 --> 00:10:44,980
really see we can learn about how much

278
00:10:48,330 --> 00:10:46,180
water there is in Jupiter's atmosphere

279
00:10:50,670 --> 00:10:48,340
remember water was one of the numbers we

280
00:10:52,800 --> 00:10:50,680
really care about then to understand

281
00:10:54,540 --> 00:10:52,810
that interior we want to know about this

282
00:10:56,250 --> 00:10:54,550
core there's a dense core way down

283
00:10:58,170 --> 00:10:56,260
inside the planet so you might think

284
00:10:59,640 --> 00:10:58,180
well our goal would be to drop something

285
00:11:02,610 --> 00:10:59,650
in and go all the way down at the core

286
00:11:06,420 --> 00:11:02,620
but the problem is that Jupiter is so

287
00:11:08,730 --> 00:11:06,430
huge it's so much mass that by the time

288
00:11:10,770 --> 00:11:08,740

you get a tiny fraction of the way in to

289
00:11:13,050 --> 00:11:10,780
the planet the pressure from all that

290
00:11:16,650 --> 00:11:13,060
mass above you the gravity is squeezing

291
00:11:18,270 --> 00:11:16,660
it so much the pressure gets up to 1020

292
00:11:20,910 --> 00:11:18,280
a hundred times the pressure here on the

293
00:11:22,590 --> 00:11:20,920
earth by the time you get a quarter or a

294
00:11:24,420 --> 00:11:22,600
third of the way in the pressure is

295
00:11:25,470 --> 00:11:24,430
millions of times the pressure here on

296
00:11:27,630 --> 00:11:25,480
the earth we don't know how to build

297
00:11:29,550 --> 00:11:27,640
anything that can survive that and get

298
00:11:31,440 --> 00:11:29,560
down at the interior so we have to

299
00:11:34,940 --> 00:11:31,450
measure that core without touching it

300
00:11:37,350 --> 00:11:34,950
and the way we do that is we use gravity

301
00:11:39,900 --> 00:11:37,360
because gravity comes from the entire

302
00:11:41,910 --> 00:11:39,910
planet including the core and we use the

303
00:11:44,040 --> 00:11:41,920
magnetic field because the magnetic

304
00:11:45,480 --> 00:11:44,050
field comes from deep inside the planet

305
00:11:49,620 --> 00:11:45,490
it comes from an ocean of liquid

306
00:11:51,030 --> 00:11:49,630
metallic hydrogen inside Jupiter so of

307
00:11:53,340 --> 00:11:51,040
course you know I talked about you know

308
00:11:56,400 --> 00:11:53,350
a lot and I get to say that phrase

309
00:11:58,620 --> 00:11:56,410
liquid metallic hydrogen a lot and every

310
00:12:01,440 --> 00:11:58,630
time I do I always want to stop and make

311
00:12:06,210 --> 00:12:01,450
you think about all three words it's

312
00:12:07,829 --> 00:12:06,220
liquid metallic hydrogen so if I had a

313
00:12:10,470 --> 00:12:07,839

balloon full of hydrogen here in the

314
00:12:13,079 --> 00:12:10,480
room it would float up into the sky it's

315
00:12:16,530 --> 00:12:13,089
the lightest element there is but on

316
00:12:18,510 --> 00:12:16,540
Jupiter a quarter or a third away of the

317
00:12:20,220 --> 00:12:18,520
way you're so into the planet the

318
00:12:22,140 --> 00:12:20,230
pressure gets up to about two million

319
00:12:24,450 --> 00:12:22,150
bars two million times the pressure here

320
00:12:26,820 --> 00:12:24,460
in the room that pressure is so high

321
00:12:30,000 --> 00:12:26,830
that not only is hydrogen gas squeezed

322
00:12:32,280 --> 00:12:30,010
down so much it becomes a liquid but in

323
00:12:34,350 --> 00:12:32,290
effect the electrons are squeezed right

324
00:12:36,200 --> 00:12:34,360
off the atoms it conducts electricity

325
00:12:39,660 --> 00:12:36,210
it's a liquid metal

326
00:12:42,060 --> 00:12:39,670
it's the swirling motion of that liquid

327
00:12:44,460 --> 00:12:42,070
metal hydrogen that makes the magnetic

328
00:12:46,199 --> 00:12:44,470
field so by measuring the magnetic field

329
00:12:47,890 --> 00:12:46,209
we're learning about the deep interior

330
00:12:49,870 --> 00:12:47,900
and

331
00:12:52,710 --> 00:12:49,880
I said gravity comes from the entire

332
00:12:55,300 --> 00:12:52,720
planet Jupiter's rotating every 10 hours

333
00:12:58,330 --> 00:12:55,310
300 times the mass of the earth rotating

334
00:13:00,790 --> 00:12:58,340
more than twice as fast so it bulges out

335
00:13:03,490 --> 00:13:00,800
at the equator right so when a

336
00:13:06,610 --> 00:13:03,500
spacecraft Falls past the planet when it

337
00:13:08,080 --> 00:13:06,620
goes past that bulge it speeds up as the

338
00:13:09,940 --> 00:13:08,090

gravity from the Bulge part of the

339
00:13:12,010 --> 00:13:09,950
planet is pulling it forward and then

340
00:13:13,330 --> 00:13:12,020
when it passes over it it slows down a

341
00:13:15,970 --> 00:13:13,340
little because gravity is pulling it

342
00:13:18,310 --> 00:13:15,980
back in the other direction so by

343
00:13:19,300 --> 00:13:18,320
measuring very accurately the speed of

344
00:13:21,820 --> 00:13:19,310
the spacecraft

345
00:13:24,310 --> 00:13:21,830
we're in effect measuring the gravity of

346
00:13:26,710 --> 00:13:24,320
Jupiter and how it stretches when it

347
00:13:29,380 --> 00:13:26,720
rotates and of course a dense core in

348
00:13:31,540 --> 00:13:29,390
the center will stretch differently then

349
00:13:33,130 --> 00:13:31,550
not a dense core or a larger one will

350
00:13:35,350 --> 00:13:33,140
stress stretch differently than a

351
00:13:36,730 --> 00:13:35,360
smaller one so by very accurately

352
00:13:39,010 --> 00:13:36,740
measuring the gravity we can learn about

353
00:13:40,690 --> 00:13:39,020
the interior all right so that's the

354
00:13:42,610 --> 00:13:40,700
basic idea of how the spacecraft works

355
00:13:44,320 --> 00:13:42,620
you can see the color coding here for

356
00:13:45,850 --> 00:13:44,330
all the instruments you can see this

357
00:13:48,790 --> 00:13:45,860
orange stuff that represents the

358
00:13:50,530 --> 00:13:48,800
radiation belts Jupiter's surrounded by

359
00:13:52,360 --> 00:13:50,540
high-energy particles trapped in its

360
00:13:54,670 --> 00:13:52,370
magnetic field and they're a danger to

361
00:13:56,110 --> 00:13:54,680
the spacecraft so we have to try to

362
00:13:58,510 --> 00:13:56,120
that's one of the reasons we're in this

363
00:13:59,800 --> 00:13:58,520

big 53 day orbit we have to try to try

364
00:14:01,960 --> 00:13:59,810
to go quickly through the radiation

365
00:14:04,240 --> 00:14:01,970
belts so the electronics don't get too

366
00:14:05,830 --> 00:14:04,250
damaged and we go really close to the

367
00:14:08,290 --> 00:14:05,840
planet both because we want to measure

368
00:14:10,120 --> 00:14:08,300
things and get really close and because

369
00:14:12,970 --> 00:14:10,130
there's a gap in the radiation belts

370
00:14:15,310 --> 00:14:12,980
near the planet so all this stuff

371
00:14:16,840 --> 00:14:15,320
trapped in the high-energy high-energy

372
00:14:19,120 --> 00:14:16,850
particles trapped in the magnetic field

373
00:14:21,280 --> 00:14:19,130
is dangerous to us and we want to avoid

374
00:14:23,590 --> 00:14:21,290
it unfortunately it goes around Jupiter

375
00:14:25,510 --> 00:14:23,600
like kind of a big donut and we can fly

376
00:14:28,000 --> 00:14:25,520
over the top of it where there isn't too

377
00:14:31,300 --> 00:14:28,010
much radiation get way far away from the

378
00:14:33,160 --> 00:14:31,310
planet and then come back again every 53

379
00:14:37,480 --> 00:14:33,170
days so that's what we do and I'm

380
00:14:39,070 --> 00:14:37,490
finally off this slide okay so what you

381
00:14:43,210 --> 00:14:39,080
all want to know is what have we learned

382
00:14:46,300 --> 00:14:43,220
right all right so we've published about

383
00:14:49,570 --> 00:14:46,310
80 papers or so so far and we have

384
00:14:52,660 --> 00:14:49,580
another hundred or so in the works so at

385
00:14:56,200 --> 00:14:52,670
about a minute per paper that's about

386
00:14:57,760 --> 00:14:56,210
three hours which means I'm not going to

387
00:15:00,280 --> 00:14:57,770
tell you everything and I better give

388
00:15:03,420 --> 00:15:00,290

you the short version so here's the

389
00:15:06,750 --> 00:15:03,430
short version it's a whole new Jupiter

390
00:15:09,550 --> 00:15:06,760
every major area in which we measured

391
00:15:13,270 --> 00:15:09,560
things for the first time every way in

392
00:15:14,980 --> 00:15:13,280
which our experiments our spacecraft was

393
00:15:16,990 --> 00:15:14,990
doing something new with Jupiter and

394
00:15:20,530 --> 00:15:17,000
looking at it in a way that hadn't been

395
00:15:22,360 --> 00:15:20,540
done before we found big surprises all

396
00:15:26,440 --> 00:15:22,370
the stuff people thought they knew about

397
00:15:28,150 --> 00:15:26,450
Jupiter that we went to measure the

398
00:15:28,780 --> 00:15:28,160
original theories were wrong they needed

399
00:15:31,210 --> 00:15:28,790
to be fixed

400
00:15:33,450 --> 00:15:31,220
based on the data so as somebody who

401
00:15:36,850 --> 00:15:33,460
measures stuff as an experimentalist

402
00:15:38,410 --> 00:15:36,860
that's really fun making the theorists

403
00:15:41,800 --> 00:15:38,420
throw out all their theories is really

404
00:15:43,450 --> 00:15:41,810
great and we got to do that a lot all

405
00:15:44,830 --> 00:15:43,460
right so let's go through a few of them

406
00:15:47,170 --> 00:15:44,840
as I said I'm not gonna be able to tell

407
00:15:49,420 --> 00:15:47,180
you everything but I'll tell you some of

408
00:15:50,740 --> 00:15:49,430
the highlights and then I'll take

409
00:15:51,610 --> 00:15:50,750
questions at the end and maybe we can

410
00:15:54,130 --> 00:15:51,620
talk about other stuff

411
00:15:55,960 --> 00:15:54,140
all right so very first thing pretty

412
00:15:59,200 --> 00:15:55,970
much first day we got good data which

413
00:16:02,740 --> 00:15:59,210

was August 27th 2016 we went into orbit

414
00:16:04,180 --> 00:16:02,750
on 4th of July 2016 but since we were

415
00:16:05,440 --> 00:16:04,190
firing the main engine and going into

416
00:16:07,630 --> 00:16:05,450
orbit we didn't have all the science

417
00:16:09,820 --> 00:16:07,640
instruments on came around 53 days later

418
00:16:11,830 --> 00:16:09,830
and that's when we took our first good

419
00:16:13,930 --> 00:16:11,840
set of science data very first thing we

420
00:16:16,060 --> 00:16:13,940
saw really was pictures of the north and

421
00:16:17,980 --> 00:16:16,070
south pole of Jupiter and they don't

422
00:16:21,280 --> 00:16:17,990
look anything like to Peter Dunne's from

423
00:16:24,310 --> 00:16:21,290
the side so on the right there is a nice

424
00:16:25,990 --> 00:16:24,320
picture of Jupiter with about how you'd

425
00:16:28,750 --> 00:16:26,000
see it from the earth with a really good

426
00:16:31,240 --> 00:16:28,760
telescope I think that actually might be

427
00:16:33,940 --> 00:16:31,250
from Cassini or something but it's it's

428
00:16:35,890 --> 00:16:33,950
how Jupiter looks from the side belts

429
00:16:38,290 --> 00:16:35,900
and zones orange and white stripes the

430
00:16:40,930 --> 00:16:38,300
Great Red Spot all of that stuff on the

431
00:16:42,970 --> 00:16:40,940
left is a picture of the South Pole and

432
00:16:46,990 --> 00:16:42,980
a picture of the North Pole from our

433
00:16:49,030 --> 00:16:47,000
first pass so of course you only have

434
00:16:50,890 --> 00:16:49,040
it's only half lit by the Sun right you

435
00:16:53,080 --> 00:16:50,900
have to go by again and get to put her

436
00:16:55,150 --> 00:16:53,090
in a different rotation to see the rest

437
00:16:58,120 --> 00:16:55,160
of it but already you can see from that

438
00:16:59,710 --> 00:16:58,130

that it looks like you're looking at a

439
00:17:03,730 --> 00:16:59,720
different planet it doesn't even look

440
00:17:05,260 --> 00:17:03,740
similar so all these things that you're

441
00:17:08,000 --> 00:17:05,270
seeing that what kind of like craters or

442
00:17:10,189 --> 00:17:08,010
something those are storms those

443
00:17:13,210 --> 00:17:10,199
storms most of them or many of them

444
00:17:16,460 --> 00:17:13,220
bigger than the whole United States

445
00:17:18,470 --> 00:17:16,470
bigger than continents here and there

446
00:17:20,630 --> 00:17:18,480
storms in the north and in the south and

447
00:17:24,199 --> 00:17:20,640
they they last for really long time

448
00:17:26,360 --> 00:17:24,209
there's a zillion of them and we don't

449
00:17:28,700 --> 00:17:26,370
see the continuation the belts and zones

450
00:17:31,340 --> 00:17:28,710
we don't see the kind of pattern we saw

451
00:17:33,800 --> 00:17:31,350
at Saturn basically this was a big

452
00:17:36,320 --> 00:17:33,810
surprise and there were more surprises

453
00:17:41,660 --> 00:17:36,330
to come just from that from looking at

454
00:17:43,580 --> 00:17:41,670
the North and South Poles so what you're

455
00:17:45,410 --> 00:17:43,590
looking at now is a composite image

456
00:17:46,940 --> 00:17:45,420
where we've put together a bunch of

457
00:17:48,830 --> 00:17:46,950
different views so that we can get the

458
00:17:51,980 --> 00:17:48,840
whole in this case I think that's the

459
00:17:55,070 --> 00:17:51,990
South Pole and we've exaggerated the

460
00:17:57,830 --> 00:17:55,080
color so the colors been stretched it's

461
00:18:00,140 --> 00:17:57,840
not that blue at the South Pole but it's

462
00:18:03,380 --> 00:18:00,150
definitely bluer at the South Pole than

463
00:18:06,350 --> 00:18:03,390

it is at the equator at Jupiter and no

464
00:18:08,030 --> 00:18:06,360
we don't know why yet but for some

465
00:18:09,230 --> 00:18:08,040
reason the gases were looking at at

466
00:18:11,300 --> 00:18:09,240
Jupiter it's got to be something about

467
00:18:13,970 --> 00:18:11,310
what what gases we're seeing so it's

468
00:18:16,100 --> 00:18:13,980
different composition is bluer up near

469
00:18:19,550 --> 00:18:16,110
the poles than it is down at the equator

470
00:18:21,290 --> 00:18:19,560
and there's circumpolar cyclones now

471
00:18:23,810 --> 00:18:21,300
those are a little hard to see in this

472
00:18:25,700 --> 00:18:23,820
visible light picture because we had to

473
00:18:28,160 --> 00:18:25,710
make a composite image and it's lit from

474
00:18:29,860 --> 00:18:28,170
the side and you're learning a lot we

475
00:18:32,240 --> 00:18:29,870
get to watch them and see some details

476
00:18:34,340 --> 00:18:32,250
but we see different details with the

477
00:18:36,560 --> 00:18:34,350
infrared camera so here's the

478
00:18:39,830 --> 00:18:36,570
italian-made infrared camera Jairam it's

479
00:18:42,140 --> 00:18:39,840
called because Jovian infrared a rural

480
00:18:44,150 --> 00:18:42,150
mapper because it's main job is to look

481
00:18:45,860 --> 00:18:44,160
at the Aurora the northern the northern

482
00:18:47,780 --> 00:18:45,870
and southern lights on Jupiter but does

483
00:18:52,450 --> 00:18:47,790
a great job of looking at the poles and

484
00:18:54,920 --> 00:18:52,460
what you can see is five cyclones

485
00:18:56,720 --> 00:18:54,930
gathered around the South Pole and a

486
00:19:00,950 --> 00:18:56,730
pentagon with another cyclone in the

487
00:19:03,410 --> 00:19:00,960
center and eight cyclones gathered

488
00:19:06,320 --> 00:19:03,420

around the North Pole with another

489
00:19:09,350 --> 00:19:06,330
cyclone in the center and that pattern

490
00:19:11,480 --> 00:19:09,360
is pretty stable we've been we've been

491
00:19:13,640 --> 00:19:11,490
watching it for almost two years now and

492
00:19:16,280 --> 00:19:13,650
it hasn't changed they're slowly

493
00:19:18,590 --> 00:19:16,290
drifting around a little bit but it's

494
00:19:21,290 --> 00:19:18,600
basically this stable pattern of five in

495
00:19:21,410 --> 00:19:21,300
the South eight in the north we don't

496
00:19:25,610 --> 00:19:21,420
know

497
00:19:28,520 --> 00:19:25,620
eight people working on a lot of

498
00:19:30,080 --> 00:19:28,530
theories about why the Cyclones should

499
00:19:32,240 --> 00:19:30,090
be there and they're starting to come up

500
00:19:33,890 --> 00:19:32,250
with some models that maybe Canon can

501
00:19:36,230 --> 00:19:33,900
explain it but this was a big surprise

502
00:19:37,370 --> 00:19:36,240
and then if you look carefully at this

503
00:19:41,060 --> 00:19:37,380
there's another really interesting

504
00:19:42,470 --> 00:19:41,070
feature of this these are all cyclones

505
00:19:45,080 --> 00:19:42,480
they're not anticyclones they're all

506
00:19:47,420 --> 00:19:45,090
spinning the same direction so if you

507
00:19:49,970 --> 00:19:47,430
imagine this cyclone spinning around and

508
00:19:53,690 --> 00:19:49,980
the one next to it spinning around and

509
00:19:55,340 --> 00:19:53,700
picture what happens in between and with

510
00:19:57,520 --> 00:19:55,350
this one in the center is spinning the

511
00:20:00,500 --> 00:19:57,530
same direction what happens in between

512
00:20:02,660 --> 00:20:00,510
it's not like gears that can spin and

513
00:20:04,580 --> 00:20:02,670

match up to do that you'd have to have

514
00:20:07,580 --> 00:20:04,590
some of them spinning in the opposite

515
00:20:09,980 --> 00:20:07,590
direction so in the place right in

516
00:20:12,440 --> 00:20:09,990
between the Cyclones you've got wind

517
00:20:14,000 --> 00:20:12,450
going really fast in this direction and

518
00:20:17,240 --> 00:20:14,010
right next to it wind going really fast

519
00:20:19,130 --> 00:20:17,250
in the opposite direction so something

520
00:20:21,830 --> 00:20:19,140
has to be driving that so they don't all

521
00:20:25,340 --> 00:20:21,840
stop or swallow each other or do

522
00:20:26,840 --> 00:20:25,350
something to change that situation so

523
00:20:28,760 --> 00:20:26,850
this is a really interesting puzzle for

524
00:20:31,010 --> 00:20:28,770
the atmospheric folks to work on that

525
00:20:33,170 --> 00:20:31,020
was probably our first big surprise that

526
00:20:35,750 --> 00:20:33,180
Jupiter was seeing all these storms and

527
00:20:38,000 --> 00:20:35,760
seeing how different the poles look but

528
00:20:40,520 --> 00:20:38,010
the infrared camera you can also learn

529
00:20:42,350 --> 00:20:40,530
about not just you know you can see in

530
00:20:45,890 --> 00:20:42,360
the dark so you get a cleaner picture

531
00:20:47,600 --> 00:20:45,900
but you're seeing the temperature in the

532
00:20:51,050 --> 00:20:47,610
infrared you're seeing the the glow from

533
00:20:54,410 --> 00:20:51,060
the fact that these gases are are warm

534
00:20:55,610 --> 00:20:54,420
and warmer gases glow more so by

535
00:20:58,210 --> 00:20:55,620
measuring how bright it is you're

536
00:21:01,190 --> 00:20:58,220
measuring what its temperature is and

537
00:21:03,650 --> 00:21:01,200
Jupiter is warmer on the inside than it

538
00:21:06,710 --> 00:21:03,660

is on the outside the reason is that

539
00:21:09,620 --> 00:21:06,720
it's still cooling off four-and-a-half

540
00:21:12,230 --> 00:21:09,630
billion years after it formed it's so

541
00:21:15,110 --> 00:21:12,240
big that it's heat of formation hasn't

542
00:21:16,040 --> 00:21:15,120
escaped yet but the result of that is if

543
00:21:18,260 --> 00:21:16,050
you know the temperature you know

544
00:21:21,170 --> 00:21:18,270
something about the depth so we were

545
00:21:23,260 --> 00:21:21,180
able to make this little movie which I

546
00:21:27,070 --> 00:21:23,270
think is about to start yeah

547
00:21:40,560 --> 00:21:27,080
and showing 3d something like what those

548
00:21:59,610 --> 00:21:54,790
[Music]

549
00:22:02,590 --> 00:22:01,740
things are thousands of kilometres

550
00:22:16,040 --> 00:22:02,600
across

551
00:22:44,120 --> 00:22:27,490
[Music]

552
00:22:48,060 --> 00:22:46,140
all right so we could talk about just

553
00:22:49,590 --> 00:22:48,070
the poles of Jupiter for an hour but

554
00:22:52,650 --> 00:22:49,600
let's move on and get a couple of other

555
00:22:54,500 --> 00:22:52,660
things fit in here so remember I said

556
00:22:56,970 --> 00:22:54,510
we're mapping Jupiter's magnetic field

557
00:22:59,880 --> 00:22:56,980
well because we're in a polar orbit we

558
00:23:01,850 --> 00:22:59,890
can end in a big long one at 53 days we

559
00:23:04,500 --> 00:23:01,860
can take advantage of that orbit and

560
00:23:06,450 --> 00:23:04,510
adjust the timing of when we go by

561
00:23:09,240 --> 00:23:06,460
Jupiter each time to get a different

562
00:23:11,340 --> 00:23:09,250
stripe so what you're seeing is lines to

563
00:23:14,190 --> 00:23:11,350

represent the path of the spacecraft in

564
00:23:16,380 --> 00:23:14,200
the rotating field point of view of

565
00:23:18,750 --> 00:23:16,390
Jupiter so if you were somehow magically

566
00:23:21,030 --> 00:23:18,760
standing on top of the clouds on Jupiter

567
00:23:22,470 --> 00:23:21,040
and spinning around with it that's the

568
00:23:24,960 --> 00:23:22,480
path you would see this pay the

569
00:23:30,180 --> 00:23:24,970
spacecraft take for each of our mini

570
00:23:32,520 --> 00:23:30,190
orbits which means when we're done with

571
00:23:35,760 --> 00:23:32,530
all of the orbits with 32 orbits around

572
00:23:37,650 --> 00:23:35,770
Jupiter we've cast a net over the planet

573
00:23:40,080 --> 00:23:37,660
and if we measure the magnetic field

574
00:23:42,420 --> 00:23:40,090
along the way on all of those orbits

575
00:23:44,070 --> 00:23:42,430
then we've surrounded Jupiter and

576
00:23:47,070 --> 00:23:44,080
measured the magnetic field completely

577
00:23:51,150 --> 00:23:47,080
surrounding it so if you know a little

578
00:23:52,950 --> 00:23:51,160
bit about electro magnetics then what

579
00:23:55,140 --> 00:23:52,960
that tells you is if I've measured the

580
00:23:56,370 --> 00:23:55,150
magnetic field on a surface that I've

581
00:23:58,800 --> 00:23:56,380
learned what's happening with the

582
00:24:00,960 --> 00:23:58,810
currents inside that surface or to put

583
00:24:03,240 --> 00:24:00,970
it another way if I measure the magnetic

584
00:24:05,160 --> 00:24:03,250
field all around Jupiter then I know

585
00:24:08,250 --> 00:24:05,170
what that liquid metallic hydrogen is

586
00:24:10,460 --> 00:24:08,260
doing deep inside we can understand the

587
00:24:13,020 --> 00:24:10,470
dynamo that generates the magnetic field

588
00:24:15,420 --> 00:24:13,030

by measuring the magnetic field on a

589
00:24:17,580 --> 00:24:15,430
complete surface that could encloses the

590
00:24:19,860 --> 00:24:17,590
planet so that's the goal of the mapping

591
00:24:21,840 --> 00:24:19,870
experiment now of course we've only

592
00:24:26,190 --> 00:24:21,850
completed a dozen or so orbits so far

593
00:24:28,680 --> 00:24:26,200
and as you saw in that map we do them in

594
00:24:30,930 --> 00:24:28,690
an order so that the first four are

595
00:24:32,820 --> 00:24:30,940
evenly spaced and then the next four

596
00:24:34,590 --> 00:24:32,830
fill in so that we get eight evenly

597
00:24:36,090 --> 00:24:34,600
spaced around the planet and then it

598
00:24:38,310 --> 00:24:36,100
takes a while you need eight more to get

599
00:24:40,560 --> 00:24:38,320
sixteen filled in around the planet so

600
00:24:42,690 --> 00:24:40,570
we've got eight evenly spaced orbits

601
00:24:44,580 --> 00:24:42,700
around the planet so far and a few

602
00:24:48,740 --> 00:24:44,590
others that will go into the next map

603
00:24:51,330 --> 00:24:48,750
but the magnetometer team made a map of

604
00:24:53,700 --> 00:24:51,340
the magnetic field on Jupiter based on

605
00:24:56,430 --> 00:24:53,710
those on the eight good ones

606
00:25:00,090 --> 00:24:56,440
far right then we're evenly-spaced and

607
00:25:02,250 --> 00:25:00,100
that was a big surprise so what's being

608
00:25:04,110 --> 00:25:02,260
shown here was just superimposing on

609
00:25:06,269 --> 00:25:04,120
jupiter a map of that magnetic field

610
00:25:07,680 --> 00:25:06,279
where it shows you the strength of the

611
00:25:09,510 --> 00:25:07,690
magnetic field that of course magnetic

612
00:25:11,100 --> 00:25:09,520
fields have direction the direction of

613
00:25:12,810 --> 00:25:11,110

the magnetic fields so red and blue show

614
00:25:16,710 --> 00:25:12,820
you into the planet and out of the

615
00:25:18,810 --> 00:25:16,720
planet and what you can see is doesn't

616
00:25:20,490 --> 00:25:18,820
look like a dipole field like the

617
00:25:21,810 --> 00:25:20,500
Earth's a nice smooth thing coming out

618
00:25:23,639 --> 00:25:21,820
of the North Pole and going into the

619
00:25:25,500 --> 00:25:23,649
South Pole it's got all kinds of

620
00:25:28,289 --> 00:25:25,510
variation and all kinds of spatial

621
00:25:31,019 --> 00:25:28,299
variation much on a finer scale finer

622
00:25:34,789 --> 00:25:31,029
scale that we expected so more variable

623
00:25:37,440 --> 00:25:34,799
on smaller patches on the planet right

624
00:25:40,200 --> 00:25:37,450
and it's also got a whole lot more

625
00:25:43,110 --> 00:25:40,210
variation in the north part of the

626
00:25:45,840 --> 00:25:43,120
planet than in the south I'm gonna run

627
00:25:52,710 --> 00:25:45,850
that little movie again just because it

628
00:25:54,810 --> 00:25:52,720
goes by kind of fast so you can see it

629
00:25:57,419 --> 00:25:54,820
again and watch for this time as you see

630
00:25:58,799 --> 00:25:57,429
all this math how this map shows up we

631
00:26:02,610 --> 00:25:58,809
all have all these Wiggles up in the

632
00:26:05,159 --> 00:26:02,620
north the Northern Hemisphere and a blue

633
00:26:06,899 --> 00:26:05,169
spot showing up then the near the

634
00:26:08,880 --> 00:26:06,909
equator so a local place where the

635
00:26:11,669 --> 00:26:08,890
magnetic field is stronger and somehow

636
00:26:14,340 --> 00:26:11,679
coming out of the planet and kind of

637
00:26:17,399 --> 00:26:14,350
smooth in the south so it's asymmetric

638
00:26:20,760 --> 00:26:17,409

it's got a lot more variation in it if

639
00:26:22,590 --> 00:26:20,770
you think about what that means what it

640
00:26:26,669 --> 00:26:22,600
tells us about the liquid metallic

641
00:26:28,860 --> 00:26:26,679
hydrogen deep inside is it says that at

642
00:26:31,230 --> 00:26:28,870
least part of it the part with all those

643
00:26:32,820 --> 00:26:31,240
wiggles part of the magnetic field must

644
00:26:35,909 --> 00:26:32,830
have been generated closer to the

645
00:26:39,120 --> 00:26:35,919
surface because if it was generated way

646
00:26:41,730 --> 00:26:39,130
down inside then what we would measure

647
00:26:44,850 --> 00:26:41,740
from our spacecraft that stays up above

648
00:26:48,029 --> 00:26:44,860
the planet would have smoothed out by

649
00:26:49,919 --> 00:26:48,039
the time it got to us all of those

650
00:26:52,019 --> 00:26:49,929
Wiggles are telling us that the magnetic

651
00:26:54,990 --> 00:26:52,029
field has generated higher up in

652
00:26:58,560 --> 00:26:55,000
Jupiter's massive atmosphere than we

653
00:27:00,090 --> 00:26:58,570
expected so instead of being all of it

654
00:27:02,490 --> 00:27:00,100
generated down in the liquid metallic

655
00:27:04,919 --> 00:27:02,500
hydrogen it looks like maybe part of

656
00:27:06,130 --> 00:27:04,929
that magnetic field is generated above

657
00:27:08,950 --> 00:27:06,140
the liquid map

658
00:27:11,770 --> 00:27:08,960
hydrogen maybe in a place where the gas

659
00:27:13,230 --> 00:27:11,780
is is partially ionized where it

660
00:27:15,910 --> 00:27:13,240
conducts a little bit of electricity

661
00:27:17,500 --> 00:27:15,920
enough to affect the magnetic field and

662
00:27:19,390 --> 00:27:17,510
then of course we have to try and figure

663
00:27:21,070 --> 00:27:19,400

out why it's so asymmetric why does the

664
00:27:23,440 --> 00:27:21,080
northland complete completely different

665
00:27:25,180 --> 00:27:23,450
from the South and people are working on

666
00:27:28,060 --> 00:27:25,190
it but as you might imagine nobody

667
00:27:31,450 --> 00:27:28,070
expected that and nobody really has that

668
00:27:33,790 --> 00:27:31,460
wired yet for exactly what's going on so

669
00:27:35,410 --> 00:27:33,800
that was the next big surprise is the

670
00:27:38,410 --> 00:27:35,420
magnetic field just doesn't look like

671
00:27:40,000 --> 00:27:38,420
the models matches great out far from

672
00:27:42,010 --> 00:27:40,010
the planet where we had models and we

673
00:27:43,450 --> 00:27:42,020
measured things before but these are the

674
00:27:46,150 --> 00:27:43,460
first measurements that get really close

675
00:27:49,360 --> 00:27:46,160
to the planet so you do a first kind of

676
00:27:50,920 --> 00:27:49,370
measurement you get surprised alright so

677
00:27:52,750 --> 00:27:50,930
let's move on to the next major

678
00:27:54,280 --> 00:27:52,760
measurement we do that's different than

679
00:27:57,070 --> 00:27:54,290
anything's been done before

680
00:27:59,560 --> 00:27:57,080
it's the microwave radiometer so as our

681
00:28:02,230 --> 00:27:59,570
spacecraft goes by the planet it spins

682
00:28:04,000 --> 00:28:02,240
and the microwave radiometer it's six

683
00:28:08,020 --> 00:28:04,010
different channels looks out from the

684
00:28:10,060 --> 00:28:08,030
side and observes jupiter it's not a

685
00:28:11,500 --> 00:28:10,070
radar it's not transmitting anything in

686
00:28:14,740 --> 00:28:11,510
the radio it's just looking at the

687
00:28:16,510 --> 00:28:14,750
natural radio emission from jupiter but

688
00:28:18,820 --> 00:28:16,520

we get to look at any given point along

689
00:28:20,320 --> 00:28:18,830
the path at a wide range of angles as

690
00:28:22,720 --> 00:28:20,330
you can see as the spacecraft moves

691
00:28:25,000 --> 00:28:22,730
along each time it spins it's in a

692
00:28:27,040 --> 00:28:25,010
different place and it gets to look at

693
00:28:28,600 --> 00:28:27,050
jupiter from a different angle so that

694
00:28:30,700 --> 00:28:28,610
means i have these six different

695
00:28:33,490 --> 00:28:30,710
channels that see six different depths

696
00:28:35,650 --> 00:28:33,500
and I also get to look at them at each

697
00:28:37,750 --> 00:28:35,660
with each channel at every spot at a

698
00:28:39,460 --> 00:28:37,760
wide range of angles so it's kind of

699
00:28:42,040 --> 00:28:39,470
like doing a cat scan I can kind of

700
00:28:45,640 --> 00:28:42,050
dissect what's going on inside Jupiter

701
00:28:48,010 --> 00:28:45,650
and the radiometer just measures the

702
00:28:50,020 --> 00:28:48,020
brightness it's not making a picture but

703
00:28:52,420 --> 00:28:50,030
the spot that it sees because we get so

704
00:28:54,010 --> 00:28:52,430
close to Jupiter gets pretty small so

705
00:28:57,100 --> 00:28:54,020
this is an example to show you how small

706
00:28:58,780 --> 00:28:57,110
the spots get when we're really close to

707
00:29:01,030 --> 00:28:58,790
our closest approach when we're right in

708
00:29:03,100 --> 00:29:01,040
there near the equator we can see this

709
00:29:05,590 --> 00:29:03,110
tiny little spot we're really measuring

710
00:29:07,810 --> 00:29:05,600
pretty precisely what we see on Jupiter

711
00:29:10,000 --> 00:29:07,820
and then of course as we're further away

712
00:29:13,180 --> 00:29:10,010
we're seeing a bigger part of the of the

713
00:29:14,770 --> 00:29:13,190

planet so what have we learned by

714
00:29:16,529 --> 00:29:14,780
looking beneath the clouds for the very

715
00:29:19,919 --> 00:29:16,539
first time

716
00:29:22,709 --> 00:29:19,929
well we only see a few hundred

717
00:29:25,229 --> 00:29:22,719
kilometers beneath the clouds so on the

718
00:29:26,699 --> 00:29:25,239
scale of Jupiter that's tiny right it

719
00:29:29,939 --> 00:29:26,709
looks like the you know a thin line

720
00:29:32,189 --> 00:29:29,949
there but if you think about what the

721
00:29:34,619 --> 00:29:32,199
planets made out of right it's this gas

722
00:29:37,169 --> 00:29:34,629
giant it's all hydrogen and helium and

723
00:29:39,989 --> 00:29:37,179
other stuff kids should be all swirling

724
00:29:42,839 --> 00:29:39,999
around gas so what everybody thought

725
00:29:45,060 --> 00:29:42,849
before the spacecraft got to Jupiter was

726
00:29:47,489 --> 00:29:45,070
as soon as you get deep enough to get

727
00:29:49,079 --> 00:29:47,499
below the clouds so you get below where

728
00:29:50,609 --> 00:29:49,089
water and ammonia because there's

729
00:29:53,039 --> 00:29:50,619
ammonia in the planet where water and

730
00:29:54,989 --> 00:29:53,049
ammonia condense and make clouds once

731
00:29:57,539 --> 00:29:54,999
you get below that you should be below

732
00:30:00,959 --> 00:29:57,549
the weather layer blow all the storms

733
00:30:02,999 --> 00:30:00,969
and it should just be evenly mixed so

734
00:30:04,949 --> 00:30:03,009
what we thought was our deepest channels

735
00:30:07,529 --> 00:30:04,959
that see is far into the planet as we

736
00:30:09,209 --> 00:30:07,539
can a few hundred kilometers since

737
00:30:11,789 --> 00:30:09,219
they're seeing well below all those

738
00:30:13,589 --> 00:30:11,799

clouds they should have found the same

739
00:30:17,009 --> 00:30:13,599
thing everywhere we looked and all the

740
00:30:19,079 --> 00:30:17,019
structure should have been up above the

741
00:30:21,989 --> 00:30:19,089
clouds or up in the area where the

742
00:30:23,369 --> 00:30:21,999
clouds are and higher all right well you

743
00:30:26,489 --> 00:30:23,379
know the theme of this so you know what

744
00:30:30,209 --> 00:30:26,499
I'm gonna say didn't look anything like

745
00:30:32,399 --> 00:30:30,219
that so what we did

746
00:30:35,519 --> 00:30:32,409
the easiest thing to do first so that's

747
00:30:37,799 --> 00:30:35,529
what what I'm showing you is to measure

748
00:30:40,049 --> 00:30:37,809
the opacity how much it absorbs the

749
00:30:42,959 --> 00:30:40,059
microwaves and most of that's done by

750
00:30:45,509 --> 00:30:42,969
ammonia so measuring the ammonia was the

751
00:30:47,609 --> 00:30:45,519
simplest thing to do first and what we

752
00:30:49,379 --> 00:30:47,619
found when we did that is if you take

753
00:30:52,289 --> 00:30:49,389
this strip where we were close to the

754
00:30:54,539 --> 00:30:52,299
planet we you spread it out and you plot

755
00:30:56,729 --> 00:30:54,549
up at the top of the clouds

756
00:30:59,129 --> 00:30:56,739
how much ammonia there is using color to

757
00:31:01,049 --> 00:30:59,139
show the ammonia and down at the bottom

758
00:31:04,919 --> 00:31:01,059
how much ammonia there is and everything

759
00:31:07,169 --> 00:31:04,929
in between what we see is as deep as we

760
00:31:09,959 --> 00:31:07,179
can see we're seeing structure in the

761
00:31:11,609 --> 00:31:09,969
ammonia we're seeing this place north of

762
00:31:15,779 --> 00:31:11,619
the Equator just north of the equator

763
00:31:17,399 --> 00:31:15,789

where the ammonia seems to be uniform

764
00:31:19,529 --> 00:31:17,409
with depth there maybe even getting to

765
00:31:22,079 --> 00:31:19,539
be more ammonia up at the top then down

766
00:31:23,549 --> 00:31:22,089
at the bottom and right next to it just

767
00:31:25,019 --> 00:31:23,559
north of it there's this place where

768
00:31:27,239 --> 00:31:25,029
there's a whole bunch of ammonia missing

769
00:31:29,159 --> 00:31:27,249
before it gets down to the the

770
00:31:30,240 --> 00:31:29,169
well-mixed part and this part all the

771
00:31:33,270 --> 00:31:30,250
way at the bottom Rochelle

772
00:31:35,190 --> 00:31:33,280
that is as the same ammonia all the way

773
00:31:38,430 --> 00:31:35,200
across that's because that's the deepest

774
00:31:41,100 --> 00:31:38,440
we can see we don't know how how much

775
00:31:44,370 --> 00:31:41,110
ammonia there is all the way down at the

776
00:31:46,260 --> 00:31:44,380
bottom beyond that so we said well if

777
00:31:48,450 --> 00:31:46,270
it's well mixed how deep can we show

778
00:31:50,220 --> 00:31:48,460
that it's not well mixed and it's as

779
00:31:51,750 --> 00:31:50,230
deep as we can look so it could actually

780
00:31:54,420 --> 00:31:51,760
have structure that goes even deeper

781
00:31:56,250 --> 00:31:54,430
than that then we see if you look

782
00:31:58,170 --> 00:31:56,260
carefully you're seeing more ammonia

783
00:32:01,140 --> 00:31:58,180
over here and then some missing as you

784
00:32:02,880 --> 00:32:01,150
go down and then more below that so this

785
00:32:05,390 --> 00:32:02,890
was a complete surprise and a big

786
00:32:08,580 --> 00:32:05,400
mystery as to what the heck's going on

787
00:32:10,500 --> 00:32:08,590
people have been working on that for a

788
00:32:12,330 --> 00:32:10,510

long time now we're starting to make

789
00:32:15,150 --> 00:32:12,340
inroads we're starting to have ideas

790
00:32:17,250 --> 00:32:15,160
about how this can happen and what it

791
00:32:19,170 --> 00:32:17,260
says about the circulation deep within

792
00:32:21,660 --> 00:32:19,180
the planet and of course one of the

793
00:32:23,610 --> 00:32:21,670
things we need to do is measure the rest

794
00:32:26,940 --> 00:32:23,620
of the planet remember our orbit gets

795
00:32:29,820 --> 00:32:26,950
really close here and is not as close to

796
00:32:32,430 --> 00:32:29,830
Jupiter up here over the poles but as

797
00:32:34,500 --> 00:32:32,440
the orbit progresses each orbit shifts a

798
00:32:36,780 --> 00:32:34,510
little bit so that closest approach part

799
00:32:38,670 --> 00:32:36,790
the para jove starts out down near the

800
00:32:41,610 --> 00:32:38,680
equator and it moves up a degree every

801
00:32:44,010 --> 00:32:41,620
orbit so by orbit 30 will be up here and

802
00:32:47,820 --> 00:32:44,020
be getting data up in that part of the

803
00:32:52,740 --> 00:32:47,830
planet anyway we have I'll show you the

804
00:32:54,150 --> 00:32:52,750
first nine or ten orbits now what I did

805
00:32:56,100 --> 00:32:54,160
is I took that same map and I just

806
00:32:59,010 --> 00:32:56,110
spread it out so this is latitude minus

807
00:33:01,560 --> 00:32:59,020
40 to plus 40 this is depth it's written

808
00:33:03,030 --> 00:33:01,570
in pressure but think of that as up at

809
00:33:06,930 --> 00:33:03,040
the top of the atmosphere and this is

810
00:33:08,940 --> 00:33:06,940
say 350 kilometers down inside and as

811
00:33:10,770 --> 00:33:08,950
you as you go around the planet and look

812
00:33:13,200 --> 00:33:10,780
at it at the multiple stripes we've got

813
00:33:15,510 --> 00:33:13,210

you see sure enough it's some longitudes

814
00:33:19,560 --> 00:33:15,520
it really is more ammonia up here than

815
00:33:22,080 --> 00:33:19,570
down here but this zone of ammonia that

816
00:33:24,720 --> 00:33:22,090
spreads all the way up to the top is

817
00:33:26,730 --> 00:33:24,730
there at that latitude everywhere around

818
00:33:29,010 --> 00:33:26,740
the planet so it's like a ring around

819
00:33:34,210 --> 00:33:29,020
the planet at a latitude of a few

820
00:33:42,490 --> 00:33:38,799
why why is it at the equator almost why

821
00:33:44,320 --> 00:33:42,500
is it north and not south why is it not

822
00:33:46,950 --> 00:33:44,330
matching up with the belts and zones

823
00:33:50,259 --> 00:33:46,960
very well that we see at the surface

824
00:33:51,369 --> 00:33:50,269
nobody really knows why is there ammonia

825
00:33:54,070 --> 00:33:51,379
missing here

826
00:33:55,690 --> 00:33:54,080
why is there this inversion these are

827
00:33:58,899 --> 00:33:55,700
all things we're puzzles we're trying to

828
00:34:01,360 --> 00:33:58,909
figure out with lots of ideas but we

829
00:34:02,919 --> 00:34:01,370
need a lot more data to try to figure

830
00:34:05,590 --> 00:34:02,929
them out we need to spend a lot more

831
00:34:06,940 --> 00:34:05,600
time basically building new theories

832
00:34:08,589 --> 00:34:06,950
because we made the theorist

833
00:34:13,419 --> 00:34:08,599
throw out all the theories they had

834
00:34:15,430 --> 00:34:13,429
which was really lots of fun ok you can

835
00:34:17,530 --> 00:34:15,440
also by looking at at that we have lots

836
00:34:19,389 --> 00:34:17,540
of longitudes now you can see some other

837
00:34:21,280 --> 00:34:19,399
things that are really nice to see as an

838
00:34:23,559 --> 00:34:21,290

experimentalist the fact that we're

839
00:34:24,970 --> 00:34:23,569
getting the same answer over and over is

840
00:34:27,220 --> 00:34:24,980
really good because it means our

841
00:34:29,020 --> 00:34:27,230
instruments nice and stable if there

842
00:34:31,690 --> 00:34:29,030
were problems with the instrument which

843
00:34:33,609 --> 00:34:31,700
were you know generating more noise than

844
00:34:35,200 --> 00:34:33,619
we thought it was or if we had to gain

845
00:34:36,430 --> 00:34:35,210
wrong or things like that

846
00:34:38,859 --> 00:34:36,440
then we wouldn't get this nice

847
00:34:40,780 --> 00:34:38,869
self-consistent picture and then we

848
00:34:43,419 --> 00:34:40,790
could also see some little details as

849
00:34:45,490 --> 00:34:43,429
you go to different longitudes so if you

850
00:34:48,849 --> 00:34:45,500
watch over here for example you can see

851
00:34:51,940 --> 00:34:48,859
sometimes there's more or less ammonia

852
00:34:53,649 --> 00:34:51,950
over here this thing moves around that

853
00:34:55,869 --> 00:34:53,659
varies a little bit and every once in a

854
00:34:57,790 --> 00:34:55,879
while we see something at great depth

855
00:35:00,280 --> 00:34:57,800
and that thing we're seeing that comes

856
00:35:04,120 --> 00:35:00,290
down here at about minus 20 degrees

857
00:35:04,920 --> 00:35:04,130
latitude at great depth is the great red

858
00:35:07,780 --> 00:35:04,930
spot

859
00:35:10,839 --> 00:35:07,790
so we one of our passes we flew right

860
00:35:13,839 --> 00:35:10,849
over the great red spot and what we

861
00:35:15,790 --> 00:35:13,849
found was another big surprise which is

862
00:35:21,329 --> 00:35:15,800
the great red spot goes as deep as we

863
00:35:23,980 --> 00:35:21,339

can see so about 350 kilometers at least

864
00:35:25,859 --> 00:35:23,990
the models people had theories about how

865
00:35:27,730 --> 00:35:25,869
the great red spot worked and models of

866
00:35:30,849 --> 00:35:27,740
predicting what it should be and all

867
00:35:33,970 --> 00:35:30,859
that and in general they expected it to

868
00:35:35,800 --> 00:35:33,980
be a lot shallower than that so now we

869
00:35:39,760 --> 00:35:35,810
have to explain why is the great red

870
00:35:41,170 --> 00:35:39,770
spot so deep and how does it work and we

871
00:35:42,790 --> 00:35:41,180
have some people working on that and

872
00:35:44,829 --> 00:35:42,800
some papers that'll come out before too

873
00:35:45,430 --> 00:35:44,839
long and I probably shouldn't spill the

874
00:35:47,410 --> 00:35:45,440
beans

875
00:35:50,440 --> 00:35:47,420
on those papers until we know that

876
00:35:51,700 --> 00:35:50,450
everything's right but you can tell to

877
00:35:54,160 --> 00:35:51,710
look at it if you look at this picture

878
00:35:55,630 --> 00:35:54,170
at the top that's the visible light

879
00:35:58,330 --> 00:35:55,640
picture so you can see where the great

880
00:36:01,750 --> 00:35:58,340
red spot is and then you can see from

881
00:36:03,850 --> 00:36:01,760
the red here that we've got the center

882
00:36:07,150 --> 00:36:03,860
of the great red spot looking cold in

883
00:36:10,300 --> 00:36:07,160
the upper channel so I get down to 10 20

884
00:36:14,410 --> 00:36:10,310
30 kilometers or so maybe even as deep

885
00:36:17,200 --> 00:36:14,420
as 50 or 80 kilometers and the great red

886
00:36:19,930 --> 00:36:17,210
spot is cold in the middle but when I

887
00:36:22,210 --> 00:36:19,940
get down to 150 kilometers or 350

888
00:36:25,150 --> 00:36:22,220

kilometers the great red spot is hot in

889
00:36:26,740 --> 00:36:25,160
the middle we still see it still

890
00:36:28,150 --> 00:36:26,750
definitely looks different from all the

891
00:36:30,310 --> 00:36:28,160
other passes that didn't go over the

892
00:36:33,250 --> 00:36:30,320
great red spot looks different from the

893
00:36:35,380 --> 00:36:33,260
surrounding territory but something is

894
00:36:37,660 --> 00:36:35,390
changing it's going from hot to cold as

895
00:36:41,380 --> 00:36:37,670
we go down and then there's this hot

896
00:36:42,850 --> 00:36:41,390
region just to the side of it that's

897
00:36:44,890 --> 00:36:42,860
changing and merging down with the

898
00:36:47,050 --> 00:36:44,900
bottom so we're definitely getting a

899
00:36:49,390 --> 00:36:47,060
very interesting picture of this storm

900
00:36:53,230 --> 00:36:49,400
and remember it's a storm bigger than

901
00:36:55,870 --> 00:36:53,240
the whole earth and a lot to a lot to

902
00:36:57,910 --> 00:36:55,880
chew on so I get to tell you it's a

903
00:36:59,530 --> 00:36:57,920
surprise but I don't get to tell you old

904
00:37:01,180 --> 00:36:59,540
and this is what's going on and this is

905
00:37:05,710 --> 00:37:01,190
how it works because we don't have that

906
00:37:07,120 --> 00:37:05,720
all figured out yet okay so let's move

907
00:37:08,860 --> 00:37:07,130
on to the next big thing which was the

908
00:37:11,050 --> 00:37:08,870
gravity remember gravity is trying to

909
00:37:12,430 --> 00:37:11,060
measure the interior and one of the

910
00:37:15,640 --> 00:37:12,440
first things we got out of the gravity

911
00:37:17,170 --> 00:37:15,650
was those belts and zones so remember

912
00:37:18,730 --> 00:37:17,180
those are the stripes the jet streams

913
00:37:20,950 --> 00:37:18,740

moving up at the top of Jupiter's

914
00:37:23,140 --> 00:37:20,960
atmosphere and nobody knew how deep they

915
00:37:25,480 --> 00:37:23,150
went theories ranged from all the way

916
00:37:27,850 --> 00:37:25,490
down to having them go way down deep

917
00:37:30,250 --> 00:37:27,860
inside the planet to being really

918
00:37:32,890 --> 00:37:30,260
shallow up at the top so now we know

919
00:37:35,980 --> 00:37:32,900
they go about 3,000 kilometres into

920
00:37:39,430 --> 00:37:35,990
Jupiter and that's what this little

921
00:37:42,310 --> 00:37:39,440
animation is showing and beneath the

922
00:37:44,190 --> 00:37:42,320
3,000 kilometres the rest of Jupiter

923
00:37:46,630 --> 00:37:44,200
rotates kind of like a solid body

924
00:37:51,820 --> 00:37:46,640
remember it's not a solid body it's a

925
00:37:55,450 --> 00:37:51,830
liquid down inside there but it rotates

926
00:37:58,520 --> 00:37:55,460
all together below about 3,000 kilometer

927
00:38:00,289 --> 00:37:58,530
so we learned that from the gravity so

928
00:38:02,960 --> 00:38:00,299
that the belts and zones go that deep is

929
00:38:05,569 --> 00:38:02,970
really interesting and that the interior

930
00:38:09,190 --> 00:38:05,579
rotates as a solid body is really

931
00:38:11,990 --> 00:38:09,200
interesting that was a surprise and

932
00:38:13,549 --> 00:38:12,000
we're starting to look at at that and

933
00:38:16,819 --> 00:38:13,559
it's very interesting then it's about

934
00:38:20,599 --> 00:38:16,829
three thousand kilometers because that's

935
00:38:22,640 --> 00:38:20,609
about where it might be conducting

936
00:38:25,460 --> 00:38:22,650
electricity enough to make a magnetic

937
00:38:28,670 --> 00:38:25,470
field so it could be that the magnetic

938
00:38:30,620 --> 00:38:28,680

field has something to do with holding

939
00:38:35,240 --> 00:38:30,630
the inside part and why the belts and

940
00:38:36,650 --> 00:38:35,250
zones only go that deep basically it

941
00:38:39,170 --> 00:38:36,660
would be that they go as deep as they're

942
00:38:41,270 --> 00:38:39,180
gonna get as they can until the magnetic

943
00:38:43,390 --> 00:38:41,280
field interferes with them we don't

944
00:38:45,500 --> 00:38:43,400
really know that yet it's speculation

945
00:38:47,150 --> 00:38:45,510
the other thing that we've learned

946
00:38:50,420 --> 00:38:47,160
remember we were looking for the core

947
00:38:53,960 --> 00:38:50,430
dense core down inside Jupiter so what

948
00:38:56,720 --> 00:38:53,970
we found is yes there's a dense core but

949
00:38:58,609 --> 00:38:56,730
instead of a compact core down in the

950
00:39:00,920 --> 00:38:58,619
middle where you go down and the density

951
00:39:02,390 --> 00:39:00,930
is is you know the gas in liquid and

952
00:39:04,130 --> 00:39:02,400
everything and then you get to the edge

953
00:39:06,620 --> 00:39:04,140
of the core you get a sharp boundary and

954
00:39:08,269 --> 00:39:06,630
then now we're in the dense part what we

955
00:39:11,329 --> 00:39:08,279
found is something bigger than that and

956
00:39:14,180 --> 00:39:11,339
fuzzier than that like maybe it's

957
00:39:17,269 --> 00:39:14,190
dissolving in the liquid or something so

958
00:39:19,819 --> 00:39:17,279
we found this big fuzzy core down inside

959
00:39:22,039 --> 00:39:19,829
Jupiter and now we're looking to see if

960
00:39:24,620 --> 00:39:22,049
there's an even denser one inside that

961
00:39:26,690 --> 00:39:24,630
which will take a whole lot more gravity

962
00:39:28,609 --> 00:39:26,700
measurements but again it was a big

963
00:39:30,529 --> 00:39:28,619

surprise there's a reason we're calling

964
00:39:32,900 --> 00:39:30,539
this the new Jupiter right all our ideas

965
00:39:35,809 --> 00:39:32,910
about Jupiter of the things that we

966
00:39:39,019 --> 00:39:35,819
hadn't measured yet we're wrong and we

967
00:39:41,150 --> 00:39:39,029
have a new picture of Jupiter now all

968
00:39:43,839 --> 00:39:41,160
right so that's the exciting stuff some

969
00:39:46,190 --> 00:39:43,849
of the exciting stuff from the gravity

970
00:39:48,529 --> 00:39:46,200
and I see I better hurry if I want to

971
00:39:50,829 --> 00:39:48,539
have some time for questions so let's

972
00:39:54,019 --> 00:39:50,839
talk about the magnetosphere the Aurora

973
00:39:56,359 --> 00:39:54,029
so that also was lots of big surprises

974
00:39:59,180 --> 00:39:56,369
first of all they're a lot more complex

975
00:40:01,789 --> 00:39:59,190
than we expected so what you're looking

976
00:40:02,109 --> 00:40:01,799
at here are ultraviolet images of the

977
00:40:04,150 --> 00:40:02,119
Aurora

978
00:40:06,069 --> 00:40:04,160
where we've taken lots and lots of

979
00:40:08,739 --> 00:40:06,079
pictures and added them up to make a

980
00:40:09,579 --> 00:40:08,749
composite sort of the average northern

981
00:40:11,410 --> 00:40:09,589
in Southern Lights

982
00:40:13,269 --> 00:40:11,420
how many people here have seen the

983
00:40:15,009 --> 00:40:13,279
aurora on earth have been up to see the

984
00:40:17,380 --> 00:40:15,019
Northern Lights or down south to see the

985
00:40:21,690 --> 00:40:17,390
Southern Lights so a smattering of you

986
00:40:24,309 --> 00:40:21,700
anyway well to give you an idea of

987
00:40:28,509 --> 00:40:24,319
comparison right to something to to

988
00:40:31,299 --> 00:40:28,519

scale it with this auroral circle if I

989
00:40:33,039 --> 00:40:31,309
plot the earth down on it the whole

990
00:40:36,359 --> 00:40:33,049
earth maybe it would you know fit in

991
00:40:40,239 --> 00:40:36,369
there somewhere so these are enormous

992
00:40:42,370 --> 00:40:40,249
the the auroral lights on Jupiter than

993
00:40:44,579 --> 00:40:42,380
the northern and southern lights are

994
00:40:47,019 --> 00:40:44,589
these enormous displays of raw power

995
00:40:49,660 --> 00:40:47,029
from particles smacking into the

996
00:40:51,430 --> 00:40:49,670
atmosphere and there's an auroral oval

997
00:40:53,410 --> 00:40:51,440
at least they call it an oval you can

998
00:40:56,170 --> 00:40:53,420
see it's a little odd shape here in the

999
00:40:58,269 --> 00:40:56,180
North and the South is more like a nice

1000
00:40:59,859 --> 00:40:58,279
clean oval there's an auroral oval that

1001
00:41:02,769 --> 00:40:59,869
we can see from Earth and we've seen

1002
00:41:04,779 --> 00:41:02,779
that glow and learned about the aurora

1003
00:41:07,239 --> 00:41:04,789
from Earth but there we only see it from

1004
00:41:10,029 --> 00:41:07,249
the side so we're only seeing it as it

1005
00:41:11,680 --> 00:41:10,039
comes around in our point of view and we

1006
00:41:13,779 --> 00:41:11,690
didn't get a really good look now we

1007
00:41:16,029 --> 00:41:13,789
have great pictures with the ultraviolet

1008
00:41:18,599 --> 00:41:16,039
spectrometer and the infrared camera and

1009
00:41:20,529 --> 00:41:18,609
great measurements with the particle

1010
00:41:22,299 --> 00:41:20,539
experiments that measure the particles

1011
00:41:23,979 --> 00:41:22,309
that hit the spacecraft and we see that

1012
00:41:26,109 --> 00:41:23,989
the Aurora are really complex and

1013
00:41:28,749 --> 00:41:26,119

there's all this structure going on both

1014
00:41:32,410 --> 00:41:28,759
here and in the center and if you look

1015
00:41:35,019 --> 00:41:32,420
at it in the infrared you can see an

1016
00:41:38,289 --> 00:41:35,029
amazing amount of of structure so you

1017
00:41:40,210 --> 00:41:38,299
see this main Aurora Louisville which is

1018
00:41:42,009 --> 00:41:40,220
where most of the power is but there's

1019
00:41:43,569 --> 00:41:42,019
all kinds of stuff in the polar cap that

1020
00:41:46,749 --> 00:41:43,579
we didn't really realize was there

1021
00:41:48,160 --> 00:41:46,759
there's this tail around it it's easier

1022
00:41:50,380 --> 00:41:48,170
to see in the next picture there we go

1023
00:41:52,839 --> 00:41:50,390
in that one right so the moons of

1024
00:41:54,789 --> 00:41:52,849
Jupiter leave a mark in the Aurora so

1025
00:41:58,630 --> 00:41:54,799
that one is IO is the Gately is the

1026
00:42:01,239 --> 00:41:58,640
biggest tail is this long tail caused by

1027
00:42:03,279 --> 00:42:01,249
Jupiter's moon Io and we get to see

1028
00:42:05,380 --> 00:42:03,289
amazing amount of structure and things

1029
00:42:07,210 --> 00:42:05,390
going on in there as well so we're

1030
00:42:08,920 --> 00:42:07,220
learning a lot about the Aurora of

1031
00:42:10,960 --> 00:42:08,930
Jupiter and some of the things we're

1032
00:42:14,229 --> 00:42:10,970
learning are that it's much more

1033
00:42:15,820 --> 00:42:14,239
complicated than we expected that we see

1034
00:42:18,910 --> 00:42:15,830
for example

1035
00:42:21,010 --> 00:42:18,920
the mechanism that makes the brightest

1036
00:42:23,110 --> 00:42:21,020
strongest aurora on the earth we see

1037
00:42:25,510 --> 00:42:23,120
that acceleration mechanism the way the

1038
00:42:27,340 --> 00:42:25,520

particles get sped up in Jupiter's

1039
00:42:29,710 --> 00:42:27,350
magnetosphere we see that on Jupiter and

1040
00:42:31,810 --> 00:42:29,720
it makes some of the strong Aurora but

1041
00:42:33,760 --> 00:42:31,820
not the really strongest part the really

1042
00:42:35,920 --> 00:42:33,770
strongest part of the Aurora that we see

1043
00:42:38,140 --> 00:42:35,930
is some other mechanism that we haven't

1044
00:42:41,080 --> 00:42:38,150
figured out yet for how those particles

1045
00:42:42,940 --> 00:42:41,090
get accelerated we're looking for

1046
00:42:45,040 --> 00:42:42,950
acceleration regions to see where

1047
00:42:46,780 --> 00:42:45,050
particles are streaming down or maybe

1048
00:42:48,730 --> 00:42:46,790
some of them are coming up from

1049
00:42:49,300 --> 00:42:48,740
Jupiter's atmosphere there's a lot to

1050
00:42:52,050 --> 00:42:49,310
learn

1051
00:42:54,790 --> 00:42:52,060
we've got all kinds of surprises which

1052
00:42:56,440 --> 00:42:54,800
since I need to get some time for

1053
00:42:58,390 --> 00:42:56,450
questions I'm not gonna try to go

1054
00:43:01,150 --> 00:42:58,400
through right now I'm going to move on

1055
00:43:03,100 --> 00:43:01,160
to one more thing that we learned which

1056
00:43:05,370 --> 00:43:03,110
is a new radiation belt around Jupiter

1057
00:43:08,410 --> 00:43:05,380
another surprise so the high energy

1058
00:43:11,860 --> 00:43:08,420
particle experiment the Jedi instrument

1059
00:43:15,400 --> 00:43:11,870
it's called Jovian I forget what the

1060
00:43:17,710 --> 00:43:15,410
acronym stands for a energetic detector

1061
00:43:20,050 --> 00:43:17,720
of ions or something like that that

1062
00:43:21,520 --> 00:43:20,060
detects high-energy ions found right

1063
00:43:23,800 --> 00:43:21,530

close to the planet there's a ring

1064
00:43:25,390 --> 00:43:23,810
around the planet so I'm showing you a

1065
00:43:27,400 --> 00:43:25,400
cross-section but imagine it coming

1066
00:43:32,380 --> 00:43:27,410
around in front and behind the planet as

1067
00:43:34,420 --> 00:43:32,390
well very close to Jupiter of ions that

1068
00:43:38,080 --> 00:43:34,430
we didn't expect we're seeing sulfur and

1069
00:43:40,120 --> 00:43:38,090
oxygen and hydrogen ions and we think

1070
00:43:43,540 --> 00:43:40,130
that they probably started out as atoms

1071
00:43:45,940 --> 00:43:43,550
that were ionized you know have their

1072
00:43:49,660 --> 00:43:45,950
electrons stripped off when they hit

1073
00:43:52,540 --> 00:43:49,670
Jupiter's atmosphere and created this

1074
00:43:55,210 --> 00:43:52,550
belt of ions trapped really close to the

1075
00:43:59,980 --> 00:43:55,220
planet that we're flying through so that

1076
00:44:00,390 --> 00:43:59,990
was another discovery all right get in

1077
00:44:03,910 --> 00:44:00,400
there

1078
00:44:07,050 --> 00:44:03,920
so another discovery that we made is

1079
00:44:12,280 --> 00:44:07,060
actually more about people than about

1080
00:44:14,350 --> 00:44:12,290
Jupiter which is because the the visible

1081
00:44:17,590 --> 00:44:14,360
light camera on Juno which is called

1082
00:44:21,460 --> 00:44:17,600
Juno cam we set it up basically as a

1083
00:44:23,860 --> 00:44:21,470
citizen science experiment so it's a

1084
00:44:25,600 --> 00:44:23,870
camera without a real major science team

1085
00:44:28,300 --> 00:44:25,610
to try to interpret all the data and all

1086
00:44:29,290 --> 00:44:28,310
of that stuff we basically take took the

1087
00:44:30,970 --> 00:44:29,300
raw data from that

1088
00:44:34,660 --> 00:44:30,980

put it out on the web and said hey

1089
00:44:36,880 --> 00:44:34,670
everybody go play so when we were

1090
00:44:38,560 --> 00:44:36,890
planning which images to take we got

1091
00:44:41,590 --> 00:44:38,570
collected input from the public about

1092
00:44:47,140 --> 00:44:41,600
which images to take a Jupiter when we

1093
00:44:48,640 --> 00:44:47,150
were trying to get context of what what

1094
00:44:49,990 --> 00:44:48,650
does Jupiter look like now because you

1095
00:44:51,850 --> 00:44:50,000
know it's a gas giant it's constantly

1096
00:44:54,250 --> 00:44:51,860
changing we collected images from

1097
00:44:57,490 --> 00:44:54,260
amateur astronomers to use this context

1098
00:44:59,740 --> 00:44:57,500
we let the public vote on things then we

1099
00:45:02,320 --> 00:44:59,750
put all the raw data out on the web and

1100
00:45:04,030 --> 00:45:02,330
let anybody who wanted to play with that

1101
00:45:05,230 --> 00:45:04,040
data and try to construct pictures out

1102
00:45:07,570 --> 00:45:05,240
of it you know when you take the data

1103
00:45:10,120 --> 00:45:07,580
from a camera out in space it's not just

1104
00:45:12,420 --> 00:45:10,130
like snap an image and there it is you

1105
00:45:15,400 --> 00:45:12,430
have to put all the pieces together and

1106
00:45:18,130 --> 00:45:15,410
collect you know a red green and blue

1107
00:45:20,080 --> 00:45:18,140
image together into a color image and

1108
00:45:21,820 --> 00:45:20,090
you have to work on matching up when you

1109
00:45:23,980 --> 00:45:21,830
take a picture here and a picture here

1110
00:45:25,870 --> 00:45:23,990
put them together to make a mosaic take

1111
00:45:28,060 --> 00:45:25,880
into account that the planet is curved

1112
00:45:30,970 --> 00:45:28,070
all of that stuff that is normally done

1113
00:45:34,180 --> 00:45:30,980

by a team of professional scientists has

1114
00:45:37,600 --> 00:45:34,190
been done by volunteers and they've done

1115
00:45:40,180 --> 00:45:37,610
an amazing job it's absolutely

1116
00:45:42,340 --> 00:45:40,190
spectacular what we learned is if you

1117
00:45:48,040 --> 00:45:42,350
let people play they'll do amazing

1118
00:45:49,660 --> 00:45:48,050
things so there are some I hesitate to

1119
00:45:52,180 --> 00:45:49,670
call them amateurs there are some

1120
00:45:55,000 --> 00:45:52,190
citizen scientists out there who don't

1121
00:45:56,800 --> 00:45:55,010
get paid to do this science but some of

1122
00:45:59,170 --> 00:45:56,810
them in their day jobs get paid to do

1123
00:46:00,820 --> 00:45:59,180
other kinds of image processing and some

1124
00:46:02,560 --> 00:46:00,830
of them are mathematicians and some of

1125
00:46:06,310 --> 00:46:02,570
them are artists and they've made

1126
00:46:08,890 --> 00:46:06,320
amazing images using the data from Juno

1127
00:46:10,930 --> 00:46:08,900
cam at Jupiter so this is just a

1128
00:46:13,030 --> 00:46:10,940
snapshot I went I don't know a week ago

1129
00:46:15,820 --> 00:46:13,040
or so to the website where all this

1130
00:46:18,730 --> 00:46:15,830
stuff gets posted and snapped an image

1131
00:46:23,770 --> 00:46:18,740
to show you and you can see if you look

1132
00:46:27,630 --> 00:46:23,780
through here some of these are useful

1133
00:46:29,770 --> 00:46:27,640
for for getting at the science and and

1134
00:46:32,830 --> 00:46:29,780
looking at all those cyclones and storms

1135
00:46:36,400 --> 00:46:32,840
and studying things and some of them are

1136
00:46:38,920 --> 00:46:36,410
artistic images where people have done I

1137
00:46:41,230 --> 00:46:38,930
think this one is somebody's taken a

1138
00:46:43,150 --> 00:46:41,240

picture of Jupiter and made it look like

1139
00:46:46,400 --> 00:46:43,160
a painting

1140
00:46:48,799 --> 00:46:46,410
so we found a lot of artists got

1141
00:46:51,200 --> 00:46:48,809
involved and we found a lot of people a

1142
00:46:53,480 --> 00:46:51,210
lot of amateur astronomers who know a

1143
00:46:54,770 --> 00:46:53,490
lot about Jupiter got involved and

1144
00:46:56,180 --> 00:46:54,780
there's been all kinds of things coming

1145
00:46:59,809 --> 00:46:56,190
out of this including a lot of science

1146
00:47:02,089 --> 00:46:59,819
so the message there is if you

1147
00:47:04,370 --> 00:47:02,099
crowdsource the science to a bunch of

1148
00:47:09,680 --> 00:47:04,380
citizen scientists they'll do amazing

1149
00:47:13,400 --> 00:47:09,690
great work okay and we also have student

1150
00:47:15,079 --> 00:47:13,410
scientists so one of my other hats is

1151
00:47:16,970 --> 00:47:15,089
the lead scientist for the cold stone

1152
00:47:19,069 --> 00:47:16,980
Apple Valley radio telescope project I

1153
00:47:20,329 --> 00:47:19,079
wasn't gonna let this opportunity go by

1154
00:47:24,319 --> 00:47:20,339
without telling you a little bit about

1155
00:47:26,000 --> 00:47:24,329
that so that's a project where students

1156
00:47:29,210 --> 00:47:26,010
all over the country over the Internet

1157
00:47:31,880 --> 00:47:29,220
run a large radio telescope that belongs

1158
00:47:35,480 --> 00:47:31,890
to NASA it's 34 meters across so 1/3 of

1159
00:47:37,460 --> 00:47:35,490
a football field and they do real

1160
00:47:40,010 --> 00:47:37,470
astronomy with it so they're learning

1161
00:47:41,660 --> 00:47:40,020
about science by doing real science one

1162
00:47:43,220 --> 00:47:41,670
of the things they do is measure the

1163
00:47:45,170 --> 00:47:43,230

radio waves from Jupiter

1164
00:47:46,940 --> 00:47:45,180
remember Jupiter surrounded by these

1165
00:47:49,789 --> 00:47:46,950
radiation belts they give off radio

1166
00:47:51,559 --> 00:47:49,799
waves so we have an experiment as I

1167
00:47:53,930 --> 00:47:51,569
talked about that looks at the radio

1168
00:47:55,250 --> 00:47:53,940
waves from the planet if you're trying

1169
00:47:57,109 --> 00:47:55,260
to look at it from Earth you have this

1170
00:47:59,720 --> 00:47:57,119
bright radio light shining in your eyes

1171
00:48:03,140 --> 00:47:59,730
it's hard to see the planet in in

1172
00:48:04,640 --> 00:48:03,150
between if you're where Juno goes then

1173
00:48:07,130 --> 00:48:04,650
this bright light is looking over your

1174
00:48:09,500 --> 00:48:07,140
shoulder mostly you get to see the

1175
00:48:13,010 --> 00:48:09,510
planet but a little bit leaks in so you

1176
00:48:16,039 --> 00:48:13,020
have to subtract the radio light from

1177
00:48:18,770 --> 00:48:16,049
the radiation belts well the students

1178
00:48:20,930 --> 00:48:18,780
are measuring that from the earth with

1179
00:48:24,680 --> 00:48:20,940
the radio telescope and that contributes

1180
00:48:26,089 --> 00:48:24,690
to our model of the radio at Jupiter so

1181
00:48:29,569 --> 00:48:26,099
they're actually contributing to the

1182
00:48:30,950 --> 00:48:29,579
project so we have real students doing

1183
00:48:32,559 --> 00:48:30,960
real science and part of the real

1184
00:48:36,109 --> 00:48:32,569
science they're doing is working with

1185
00:48:40,220 --> 00:48:36,119
Juno to supply science data that we need

1186
00:48:41,870 --> 00:48:40,230
and that means the Juno science team of

1187
00:48:43,280 --> 00:48:41,880
course participates in the classroom and

1188
00:48:44,930 --> 00:48:43,290

so forth and in the teacher trainings

1189
00:48:46,430 --> 00:48:44,940
and we actually have a few teacher

1190
00:48:48,530 --> 00:48:46,440
trainings coming up if you know anybody

1191
00:48:50,299 --> 00:48:48,540
if you know any teachers who'd like to

1192
00:48:54,500 --> 00:48:50,309
get involved with doing real astronomy

1193
00:48:55,490 --> 00:48:54,510
real radio astronomy working with the

1194
00:48:58,310 --> 00:48:55,500
Juno team and other

1195
00:48:59,750 --> 00:48:58,320
professional astronomers there's those

1196
00:49:04,160 --> 00:48:59,760
three trainings they can find all about

1197
00:49:07,880 --> 00:49:04,170
it at the the website for Gabbard

1198
00:49:12,610 --> 00:49:07,890
Galileo Gavit org there's online

1199
00:49:14,810 --> 00:49:12,620
training and so forth as well okay so I

1200
00:49:17,020 --> 00:49:14,820
finally got to the part where we get to

1201
00:49:20,150 --> 00:49:17,030
ask questions which is my favorite part

1202
00:49:22,490 --> 00:49:20,160
and I put a bunch of websites up there

1203
00:49:25,100 --> 00:49:22,500
in case you have questions you'd rather

1204
00:49:27,650 --> 00:49:25,110
look up or you want to see some of the

1205
00:49:29,060 --> 00:49:27,660
80-something papers that I mentioned

1206
00:49:31,430 --> 00:49:29,070
that have already been published that I

1207
00:49:33,560 --> 00:49:31,440
didn't get to talk about but why don't

1208
00:49:46,160 --> 00:49:33,570
we open it up for any questions that you

1209
00:49:49,130 --> 00:49:46,170
do have to ask me yeah so I'm gonna

1210
00:49:51,200 --> 00:49:49,140
repeat the question because people were

1211
00:49:52,580 --> 00:49:51,210
watching it online or see the video

1212
00:49:55,070 --> 00:49:52,590
later won't be able to tell what you

1213
00:49:56,930 --> 00:49:55,080

asked and I'm also going to mention

1214
00:49:58,250 --> 00:49:56,940
which I was supposed to do first if you

1215
00:50:00,710 --> 00:49:58,260
have a question there's a microphone

1216
00:50:01,760 --> 00:50:00,720
over there you guys can wait online to

1217
00:50:03,470 --> 00:50:01,770
ask the question on the microphone and

1218
00:50:05,630 --> 00:50:03,480
then I won't have to repeat it but his

1219
00:50:07,610 --> 00:50:05,640
question was whether there's a similar

1220
00:50:09,440 --> 00:50:07,620
spacecraft at Saturn doing similar kinds

1221
00:50:11,450 --> 00:50:09,450
of measurements so the Cassini

1222
00:50:13,220 --> 00:50:11,460
spacecraft spent a long time it's a turd

1223
00:50:16,700 --> 00:50:13,230
measuring all kinds of things doing

1224
00:50:19,400 --> 00:50:16,710
amazing science and its original mission

1225
00:50:21,200 --> 00:50:19,410
was not a lot like Juno's it was in the

1226
00:50:23,360 --> 00:50:21,210
equatorial plane so it went around the

1227
00:50:25,310 --> 00:50:23,370
planet sideways instead of over the top

1228
00:50:27,530 --> 00:50:25,320
and it was looking at the whole system

1229
00:50:29,930 --> 00:50:27,540
and it was looking at the moon Titan and

1230
00:50:31,520 --> 00:50:29,940
it had a probe that went in and did all

1231
00:50:33,140 --> 00:50:31,530
kinds of great science but it wasn't the

1232
00:50:35,900 --> 00:50:33,150
same kind of science as what we were

1233
00:50:37,340 --> 00:50:35,910
doing but when that minute when that

1234
00:50:38,870 --> 00:50:37,350
mission finished and they still had a

1235
00:50:40,700 --> 00:50:38,880
working spacecraft and they still had

1236
00:50:42,920 --> 00:50:40,710
fuel left they started working on

1237
00:50:45,590 --> 00:50:42,930
extended missions to do other things and

1238
00:50:48,620 --> 00:50:45,600

in the very last stage of that project

1239
00:50:50,990 --> 00:50:48,630
at the instigation of some of the Juno

1240
00:50:53,330 --> 00:50:51,000
scientists who were also on the Saturn

1241
00:50:56,000 --> 00:50:53,340
science team they said now that we're

1242
00:50:58,820 --> 00:50:56,010
down to the end go ahead and take a risk

1243
00:51:01,820 --> 00:50:58,830
why don't we and let's try and fly in a

1244
00:51:04,070 --> 00:51:01,830
Juno like orbit past Saturn so they did

1245
00:51:05,210 --> 00:51:04,080
they couldn't do all the same science

1246
00:51:06,470 --> 00:51:05,220
that we're doing it to put her because

1247
00:51:08,120 --> 00:51:06,480
they didn't bring instruments for that

1248
00:51:08,780 --> 00:51:08,130
purpose right remember they brought the

1249
00:51:11,150 --> 00:51:08,790
instruments they

1250
00:51:13,610 --> 00:51:11,160
for a completely different mission but

1251
00:51:15,110 --> 00:51:13,620
they were able to do some of it and they

1252
00:51:17,480 --> 00:51:15,120
learned some things about the interior

1253
00:51:18,980 --> 00:51:17,490
of Saturn which I'm sure they're not

1254
00:51:21,860 --> 00:51:18,990
ready to publish it because it's not

1255
00:51:22,850 --> 00:51:21,870
been very long since they did that but

1256
00:51:24,680 --> 00:51:22,860
we'll get to do a little bit of

1257
00:51:26,660 --> 00:51:24,690
comparison and we'll see maybe someday

1258
00:51:28,880 --> 00:51:26,670
in the future of Juno like mission will

1259
00:51:32,150 --> 00:51:28,890
be sent to Saturn to really do the job

1260
00:51:37,510 --> 00:51:32,160
the way we did it to patern earnest or

1261
00:51:43,670 --> 00:51:42,380
great yeah I have two questions the

1262
00:51:50,090 --> 00:51:43,680
first is if you could say something

1263
00:51:50,840 --> 00:51:50,100

about this metallic liquid hydrogen is

1264
00:51:55,790 --> 00:51:50,850
it

1265
00:51:59,900 --> 00:51:55,800
like lava or something and the second

1266
00:52:01,670 --> 00:51:59,910
question is my understanding is what

1267
00:52:05,030 --> 00:52:01,680
little we know about the interior of

1268
00:52:07,310 --> 00:52:05,040
Saturn is there might be a level of

1269
00:52:09,680 --> 00:52:07,320
which there's like precipitation of

1270
00:52:12,320 --> 00:52:09,690
helium or something is there any kind of

1271
00:52:15,800 --> 00:52:12,330
interesting precipitation going on

1272
00:52:17,030 --> 00:52:15,810
inside of Jupiter right okay so let's

1273
00:52:20,420 --> 00:52:17,040
start with the liquid metallic hydrogen

1274
00:52:23,410 --> 00:52:20,430
part and I'm gonna get to give you my

1275
00:52:25,670 --> 00:52:23,420
favorite answer which is nobody knows

1276
00:52:29,210 --> 00:52:25,680
but I can say a little bit more about

1277
00:52:31,010 --> 00:52:29,220
that so the way we know that there

1278
00:52:32,300 --> 00:52:31,020
should that hydrogen when you squeeze it

1279
00:52:35,300 --> 00:52:32,310
enough should make liquid metallic

1280
00:52:37,010 --> 00:52:35,310
hydrogen is from theories that are based

1281
00:52:39,500 --> 00:52:37,020
mainly on experiments where you take a

1282
00:52:42,500 --> 00:52:39,510
small pellet of hydrogen you zap it with

1283
00:52:44,210 --> 00:52:42,510
enormous really powerful lasers and for

1284
00:52:46,490 --> 00:52:44,220
a tiny fraction of a second before it

1285
00:52:48,260 --> 00:52:46,500
explodes it implodes and reaches this

1286
00:52:50,330 --> 00:52:48,270
really high pressure you try to measure

1287
00:52:52,940 --> 00:52:50,340
what's going on in that very tiny

1288
00:52:55,310 --> 00:52:52,950

fraction of a second so it's really hard

1289
00:52:57,230 --> 00:52:55,320
to do those measurements from those

1290
00:52:59,240 --> 00:52:57,240
measurements and from those models and

1291
00:53:01,100 --> 00:52:59,250
of what hydrogen should look like under

1292
00:53:03,470 --> 00:53:01,110
great pressure they made predictions

1293
00:53:05,510 --> 00:53:03,480
that it should become a metal at about

1294
00:53:08,630 --> 00:53:05,520
to melt to mega bar two million times

1295
00:53:10,790 --> 00:53:08,640
the pressure here the biggest piece of

1296
00:53:12,740 --> 00:53:10,800
information to validate that prediction

1297
00:53:15,740 --> 00:53:12,750
and make everybody say yeah liquid

1298
00:53:18,380 --> 00:53:15,750
metallic hydrogen is real is Jupiter has

1299
00:53:20,060 --> 00:53:18,390
a magnetic field and we knew that for a

1300
00:53:20,510 --> 00:53:20,070
long time we've known Jupiter had a

1301
00:53:22,040 --> 00:53:20,520
magnet

1302
00:53:23,900 --> 00:53:22,050
field for a long time because even

1303
00:53:27,770 --> 00:53:23,910
before we ever got there because you can

1304
00:53:29,180 --> 00:53:27,780
see the radio waves from the radiation

1305
00:53:31,520 --> 00:53:29,190
belts that are trapped by the magnetic

1306
00:53:33,380 --> 00:53:31,530
field to make a magnetic field on a

1307
00:53:35,350 --> 00:53:33,390
planetary scale you need a liquid that

1308
00:53:38,330 --> 00:53:35,360
conducts electricity

1309
00:53:40,160 --> 00:53:38,340
Jupiter's mostly hydrogen and helium so

1310
00:53:42,290 --> 00:53:40,170
you weren't going to have molten iron

1311
00:53:44,510 --> 00:53:42,300
like on the earth and generate anything

1312
00:53:46,880 --> 00:53:44,520
near as big a magnetic field as we what

1313
00:53:49,070 --> 00:53:46,890

we see on Jupiter so just the fact that

1314
00:53:51,440 --> 00:53:49,080
it had a magnetic field confirm the

1315
00:53:54,560 --> 00:53:51,450
hypothesis that yes hydrogen makes

1316
00:53:56,360 --> 00:53:54,570
liquid metallic hydrogen but we don't

1317
00:53:58,940 --> 00:53:56,370
have good measurements of the viscosity

1318
00:54:00,200 --> 00:53:58,950
of liquid metallic hydrogen but we have

1319
00:54:02,450 --> 00:54:00,210
his theories about what it ought to be

1320
00:54:05,240 --> 00:54:02,460
like and the conditions under which it's

1321
00:54:07,610 --> 00:54:05,250
moving are really high pressures you

1322
00:54:10,070 --> 00:54:07,620
know at 10 million times the pressure

1323
00:54:12,470 --> 00:54:10,080
here on the earth it's hard to even talk

1324
00:54:16,340 --> 00:54:12,480
about things as a liquid or a gas or a

1325
00:54:18,410 --> 00:54:16,350
solid it's different so that's kind of

1326
00:54:20,660 --> 00:54:18,420
the state of knowledge and we'll learn

1327
00:54:22,550 --> 00:54:20,670
by measuring the magnetic field remember

1328
00:54:24,590 --> 00:54:22,560
we're gonna keep mapping and get more

1329
00:54:26,480 --> 00:54:24,600
detailed map of the magnetic field when

1330
00:54:29,060 --> 00:54:26,490
we finally understand the Dynamo well

1331
00:54:30,980 --> 00:54:29,070
that will also be teaching us about the

1332
00:54:33,710 --> 00:54:30,990
properties of hydrogen what hydrogen

1333
00:54:36,080 --> 00:54:33,720
does under great pressure so we start

1334
00:54:37,540 --> 00:54:36,090
out with how does hydrogen behave let's

1335
00:54:40,100 --> 00:54:37,550
use that to figure out the dynamo

1336
00:54:42,110 --> 00:54:40,110
eventually we maybe figure out the

1337
00:54:46,430 --> 00:54:42,120
dynamo and use that to tell us how

1338
00:54:48,200 --> 00:54:46,440

hydrogen behaves ok and I forgot what

1339
00:54:50,240 --> 00:54:48,210
was your second the precipitation oh

1340
00:54:53,060 --> 00:54:50,250
right now so yes so there's probably

1341
00:54:55,580 --> 00:54:53,070
helium rain going on a Jupiter exactly

1342
00:54:58,460 --> 00:54:55,590
how much and where is something we're

1343
00:55:02,270 --> 00:54:58,470
still working on but should come out of

1344
00:55:07,010 --> 00:55:02,280
our data there's water rain no doubt on

1345
00:55:08,750 --> 00:55:07,020
Jupiter we see that in you know we've

1346
00:55:12,310 --> 00:55:08,760
seen lightning at Jupiter before we know

1347
00:55:15,200 --> 00:55:12,320
that there's liquid and solid water and

1348
00:55:18,920 --> 00:55:15,210
water in the gas state how deep that

1349
00:55:20,210 --> 00:55:18,930
rain goes probably well possibly has

1350
00:55:22,610 --> 00:55:20,220
something to do with that bizarre

1351
00:55:24,920 --> 00:55:22,620
structure we saw in the ammonia and how

1352
00:55:27,500 --> 00:55:24,930
the the atmosphere works at a few

1353
00:55:30,290 --> 00:55:27,510
hundred kilometers below the surface but

1354
00:55:33,210 --> 00:55:30,300
we don't know those answers yet I was in

1355
00:55:35,280 --> 00:55:33,220
graduate school in the early 70s

1356
00:55:41,099 --> 00:55:35,290
and they were talking about speculations

1357
00:55:43,430 --> 00:55:41,109
of metallic hydrogen in Jupiter then

1358
00:55:48,990 --> 00:55:43,440
without any bility to measure anything

1359
00:55:50,520 --> 00:55:49,000
thank you thank you are we beginning to

1360
00:55:53,450 --> 00:55:50,530
understand they're really startling

1361
00:55:56,520 --> 00:55:53,460
differences between Jupiter and Saturn

1362
00:55:58,380 --> 00:55:56,530
well we're beginning to understand the

1363
00:56:00,630 --> 00:55:58,390

really startling differences between two

1364
00:56:04,560 --> 00:56:00,640
printers and Saturn but we've got a ways

1365
00:56:06,599 --> 00:56:04,570
to go still kissed all the surface stuff

1366
00:56:09,750 --> 00:56:06,609
then you see where you know Saturn has

1367
00:56:12,150 --> 00:56:09,760
these geometric shapes at the poles that

1368
00:56:14,130 --> 00:56:12,160
have something to do with how the jet

1369
00:56:16,190 --> 00:56:14,140
streams work and Jupiter has this

1370
00:56:20,010 --> 00:56:16,200
completely different chaotic looking

1371
00:56:21,839 --> 00:56:20,020
structure on a cyclones tells you that

1372
00:56:24,359 --> 00:56:21,849
the atmospheres behave very differently

1373
00:56:26,000 --> 00:56:24,369
and maybe that shouldn't be so

1374
00:56:29,580 --> 00:56:26,010
surprising Jupiter's a lot bigger than

1375
00:56:32,070 --> 00:56:29,590
then Saturn and the heat flow and out of

1376
00:56:35,849 --> 00:56:32,080
it is different but it'll be a while I

1377
00:56:37,980 --> 00:56:35,859
think before anybody in his field feels

1378
00:56:43,680 --> 00:56:37,990
confident saying okay now I understand

1379
00:56:46,560 --> 00:56:43,690
Jupiter and Saturn hi two questions

1380
00:56:49,170 --> 00:56:46,570
first one is I've read that Juno is the

1381
00:56:51,480 --> 00:56:49,180
fastest man-made object that we've ever

1382
00:56:53,460 --> 00:56:51,490
sent out into the cosmos but I've also

1383
00:56:56,700 --> 00:56:53,470
read that it's not quite that simple

1384
00:56:58,500 --> 00:56:56,710
because I guess it's all relative so can

1385
00:56:59,940 --> 00:56:58,510
you talk a little bit about that to the

1386
00:57:03,150 --> 00:56:59,950
extent that you can in a way that I

1387
00:57:05,370 --> 00:57:03,160
might understand to answer that question

1388
00:57:08,280 --> 00:57:05,380

is this our fastest the second question

1389
00:57:12,930 --> 00:57:08,290
is why did you include a giant can

1390
00:57:14,400 --> 00:57:12,940
opener on one of the panels okay it's

1391
00:57:17,040 --> 00:57:14,410
not a giant can opener but it certainly

1392
00:57:19,440 --> 00:57:17,050
does look like one or or a bottle opener

1393
00:57:24,030 --> 00:57:19,450
anyway but let's start with this with

1394
00:57:27,990 --> 00:57:24,040
the speed record for for fastest

1395
00:57:31,010 --> 00:57:28,000
man-made object if I tell you I throw a

1396
00:57:34,410 --> 00:57:31,020
baseball and say how fast did I throw it

1397
00:57:37,109 --> 00:57:34,420
well you can measure how fast it went

1398
00:57:39,120 --> 00:57:37,119
you know here on the ground if I'm

1399
00:57:40,710 --> 00:57:39,130
sitting on a moving train that's going

1400
00:57:43,020 --> 00:57:40,720
100 miles an hour and I throw the

1401
00:57:43,559 --> 00:57:43,030
baseball suppose I've got a really good

1402
00:57:46,529 --> 00:57:43,569
arm and I

1403
00:57:49,229 --> 00:57:46,539
and throw it at 90 miles an hour the

1404
00:57:51,930 --> 00:57:49,239
trains moving in 100 maybe I threw it at

1405
00:57:53,849 --> 00:57:51,940
190 now because the trains 100 miles an

1406
00:57:55,229 --> 00:57:53,859
hour plus the 90 or if the trains going

1407
00:57:57,390 --> 00:57:55,239
the other direction maybe the baseball's

1408
00:58:00,739 --> 00:57:57,400
only going ten miles an hour I have to

1409
00:58:04,549 --> 00:58:00,749
define a reference frame I have to say

1410
00:58:08,219 --> 00:58:04,559
how fast is it moving relative to what

1411
00:58:12,209 --> 00:58:08,229
okay so if I choose the reference frame

1412
00:58:13,709 --> 00:58:12,219
carefully then I get to say that Juno is

1413
00:58:15,749 --> 00:58:13,719

the fastest thing ever built by people

1414
00:58:17,969 --> 00:58:15,759
and I'm not sure I'm getting remember

1415
00:58:18,719 --> 00:58:17,979
this exactly right but I think the way

1416
00:58:22,620 --> 00:58:18,729
it goes

1417
00:58:26,939 --> 00:58:22,630
is if you take Cape Canaveral Florida

1418
00:58:29,969 --> 00:58:26,949
and you follow it and you say where is

1419
00:58:31,859 --> 00:58:29,979
where we launched from moving in space

1420
00:58:34,890 --> 00:58:31,869
as the earth goes around the Sun and the

1421
00:58:37,289 --> 00:58:34,900
Earth rotates and Juno moves out or past

1422
00:58:40,769 --> 00:58:37,299
the Sun and so forth then at the time

1423
00:58:43,529 --> 00:58:40,779
when Juno hit its closest approach to

1424
00:58:46,289 --> 00:58:43,539
Jupiter in it's very first time when we

1425
00:58:48,689 --> 00:58:46,299
fired the main engine to slow down so

1426
00:58:51,779 --> 00:58:48,699
that we would go into orbit before we

1427
00:58:54,479 --> 00:58:51,789
did that before we fired the engine when

1428
00:58:56,189 --> 00:58:54,489
it was moving its fastest I think if I

1429
00:58:57,900 --> 00:58:56,199
remember right that's the reference

1430
00:58:59,789 --> 00:58:57,910
frame in which you get to say it's

1431
00:59:03,150 --> 00:58:59,799
faster than anything anybody else has

1432
00:59:05,249 --> 00:59:03,160
ever said so it's a pretty you know it's

1433
00:59:07,829 --> 00:59:05,259
kind of a cheat but it does tell you

1434
00:59:11,279 --> 00:59:07,839
it's moving really fast and that's

1435
00:59:13,890 --> 00:59:11,289
mostly because of Jupiter's enormous

1436
00:59:16,469 --> 00:59:13,900
gravity so another way to look at it

1437
00:59:18,390 --> 00:59:16,479
would be how fast is it moving relative

1438
00:59:20,160 --> 00:59:18,400

to Jupiter right so you ignore the earth

1439
00:59:22,380 --> 00:59:20,170
and the Sun and all the motions we did

1440
00:59:24,509 --> 00:59:22,390
to get there and you just say what's the

1441
00:59:27,029 --> 00:59:24,519
speed of the spacecraft when it goes

1442
00:59:29,609 --> 00:59:27,039
flying by Jupiter compared to the cloud

1443
00:59:31,650 --> 00:59:29,619
tops that it's flying by and then it's

1444
00:59:33,239 --> 00:59:31,660
at its fastest I think that number was

1445
00:59:37,650 --> 00:59:33,249
in the neighborhood of 30 kilometers a

1446
00:59:42,239 --> 00:59:37,660
second so you've gone all the way across

1447
00:59:45,539 --> 00:59:42,249
the LA basin it's pretty fast okay so

1448
00:59:49,349 --> 00:59:45,549
the giant can opener that's actually the

1449
00:59:52,890 --> 00:59:49,359
magnetometer boom so we have two

1450
00:59:54,719 --> 00:59:52,900
magnetometers on the spacecraft built by

1451
00:59:56,229 --> 00:59:54,729
the same team doing the same job but

1452
00:59:58,239 --> 00:59:56,239
it's not just wood

1453
01:00:00,429 --> 00:59:58,249
see part of it is if one of them breaks

1454
01:00:02,469 --> 01:00:00,439
you have another one but part of it is

1455
01:00:07,569 --> 01:00:02,479
one of them is closer to the spacecraft

1456
01:00:09,279 --> 01:00:07,579
than the other and both of them are more

1457
01:00:10,199 --> 01:00:09,289
or less as far from the spacecraft as we

1458
01:00:13,389 --> 01:00:10,209
could get them

1459
01:00:15,729 --> 01:00:13,399
so everybody somebody here I'm sure will

1460
01:00:17,349 --> 01:00:15,739
think of this immediately why do I want

1461
01:00:21,999 --> 01:00:17,359
my magnetometer really far from the

1462
01:00:23,949 --> 01:00:22,009
spacecraft right I heard at least one

1463
01:00:26,169 --> 01:00:23,959

person say it I want to measure the

1464
01:00:29,649 --> 01:00:26,179
magnetic field of Jupiter not the

1465
01:00:31,419 --> 01:00:29,659
magnetic field of the Juno spacecraft so

1466
01:00:33,099 --> 01:00:31,429
I want the magnetometer as far from the

1467
01:00:35,079 --> 01:00:33,109
spacecraft as I can get and I want the

1468
01:00:37,689 --> 01:00:35,089
spacecraft as magnetically clean as we

1469
01:00:40,359 --> 01:00:37,699
can get and it's really not eclis clean

1470
01:00:42,239 --> 01:00:40,369
the the magnetometer team the guys at

1471
01:00:44,319 --> 01:00:42,249
Goddard who built this magnetometer

1472
01:00:48,939 --> 01:00:44,329
worked really well with the spacecraft

1473
01:00:50,439 --> 01:00:48,949
team to help them measure the magnetic

1474
01:00:52,149 --> 01:00:50,449
field of parts as they were coming onto

1475
01:00:54,189 --> 01:00:52,159
the spacecraft and to figure out ways to

1476
01:00:56,199 --> 01:00:54,199
make the Mait spacecraft really

1477
01:00:57,549 --> 01:00:56,209
magnetically clean so that every time

1478
01:00:58,749 --> 01:00:57,559
you have an electric current this way

1479
01:01:00,969 --> 01:00:58,759
right next to it you have another

1480
01:01:02,619 --> 01:01:00,979
electrical current the same size going

1481
01:01:04,749 --> 01:01:02,629
the opposite direction to cancel out its

1482
01:01:07,419 --> 01:01:04,759
magnetic field not using any magnetic

1483
01:01:09,909 --> 01:01:07,429
parts all of that stuff so the

1484
01:01:12,219 --> 01:01:09,919
spacecraft has a really low magnetic

1485
01:01:14,289 --> 01:01:12,229
field and the magnetometer is really far

1486
01:01:16,269 --> 01:01:14,299
away from it and that tells you why we

1487
01:01:18,969 --> 01:01:16,279
really want to one closer to the

1488
01:01:21,009 --> 01:01:18,979

spacecraft than the other because now as

1489
01:01:22,959 --> 01:01:21,019
the spacecraft spins around and we

1490
01:01:25,029 --> 01:01:22,969
measure Jupiter's magnetic field if

1491
01:01:28,239 --> 01:01:25,039
there's a difference between the two

1492
01:01:29,949 --> 01:01:28,249
magnetometers we can tell that there's a

1493
01:01:32,799 --> 01:01:29,959
magnetic field from the spacecraft as

1494
01:01:35,499 --> 01:01:32,809
opposed to from Jupiter so we can cancel

1495
01:01:37,089 --> 01:01:35,509
that out or subtract it out and and get

1496
01:01:39,309 --> 01:01:37,099
the magnetic field of Jupiter but it

1497
01:01:43,689 --> 01:01:39,319
came out really magnetically clean so it

1498
01:01:46,719 --> 01:01:43,699
worked well yeah thanks for having me I

1499
01:01:50,759 --> 01:01:46,729
have two questions the first question is

1500
01:01:53,019 --> 01:01:50,769
about the is about the weather and the

1501
01:01:57,279 --> 01:01:53,029
circulation of gases in the atmosphere

1502
01:01:59,589 --> 01:01:57,289
and in magnetic field and I'm just

1503
01:02:03,459 --> 01:01:59,599
wondering if you can elaborate a little

1504
01:02:05,370 --> 01:02:03,469
bit more on that and also is there you

1505
01:02:09,180 --> 01:02:05,380
talked about how the movement

1506
01:02:11,490 --> 01:02:09,190
of gases or fluids in the quote

1507
01:02:14,670 --> 01:02:11,500
atmosphere of Jupiter I might be

1508
01:02:17,250 --> 01:02:14,680
generating might be generating magnetic

1509
01:02:19,230 --> 01:02:17,260
fields and I'm curious about the op and

1510
01:02:23,480 --> 01:02:19,240
the possibility of the opposite effect

1511
01:02:26,400 --> 01:02:23,490
and then my next question is about the

1512
01:02:29,550 --> 01:02:26,410
metallic hydrogen that you're discussing

1513
01:02:31,350 --> 01:02:29,560

and this the the discussion always seems

1514
01:02:35,250 --> 01:02:31,360
to be as if the metallic hydrogen is

1515
01:02:37,110 --> 01:02:35,260
pure and I'm just wondering if what

1516
01:02:41,220 --> 01:02:37,120
speculation has been done about the

1517
01:02:45,420 --> 01:02:41,230
about alloys in which other other

1518
01:02:46,860 --> 01:02:45,430
elements or not whatever elements are

1519
01:02:50,550 --> 01:02:46,870
mixed in with that and what effect that

1520
01:02:52,560 --> 01:02:50,560
has on on your calculations that's gonna

1521
01:02:55,110 --> 01:02:52,570
be a lot to talk about so all right

1522
01:02:56,520 --> 01:02:55,120
let's see what we can do let me take it

1523
01:03:00,200 --> 01:02:56,530
in reverse order because I remember the

1524
01:03:03,120 --> 01:03:00,210
lid the lid is the last question best so

1525
01:03:06,350 --> 01:03:03,130
remember that Jupiter's composition

1526
01:03:09,600 --> 01:03:06,360
while not exactly the same as the Sun is

1527
01:03:12,360 --> 01:03:09,610
similar and we know what the composition

1528
01:03:14,220 --> 01:03:12,370
of the Sun and the whole solar system is

1529
01:03:17,100 --> 01:03:14,230
it formed from the same cloud of

1530
01:03:20,250 --> 01:03:17,110
material presumably and that's mostly

1531
01:03:24,240 --> 01:03:20,260
hydrogen and helium so by the time you

1532
01:03:26,730 --> 01:03:24,250
get down even to oxygen it's a few

1533
01:03:28,980 --> 01:03:26,740
percent or something right when you get

1534
01:03:31,350 --> 01:03:28,990
down to something that might conduct

1535
01:03:34,680 --> 01:03:31,360
electricity or mix in with the metallic

1536
01:03:38,550 --> 01:03:34,690
hydrogen it's a very low percentage of

1537
01:03:41,040 --> 01:03:38,560
the material so if and there probably

1538
01:03:44,400 --> 01:03:41,050

are if there are contaminants in the

1539
01:03:47,580 --> 01:03:44,410
liquid metallic hydrogen ocean those

1540
01:03:50,910 --> 01:03:47,590
contaminants probably don't play a big

1541
01:03:54,660 --> 01:03:50,920
role because it's such a low percentage

1542
01:03:56,310 --> 01:03:54,670
of the total material now you gotta you

1543
01:03:59,220 --> 01:03:56,320
do have to be cautious about that if I

1544
01:04:00,690 --> 01:03:59,230
if I said you know I made I took iron

1545
01:04:02,340 --> 01:04:00,700
and I put a little bit of carbon trace

1546
01:04:05,100 --> 01:04:02,350
elements and it shouldn't matter much

1547
01:04:06,540 --> 01:04:05,110
you know I can make steel but that's a

1548
01:04:10,440 --> 01:04:06,550
solid with a crystalline structure

1549
01:04:12,180 --> 01:04:10,450
that's different from a liquid and even

1550
01:04:14,130 --> 01:04:12,190
there I think the percentage of carbon

1551
01:04:15,930 --> 01:04:14,140
is probably higher than percentage of

1552
01:04:18,800 --> 01:04:15,940
the law of trace elements in the

1553
01:04:21,210 --> 01:04:18,810
metallic hydrogen so

1554
01:04:23,580 --> 01:04:21,220
I'm not gonna try to go beyond that

1555
01:04:25,200 --> 01:04:23,590
because I don't know the answers I'm

1556
01:04:27,690 --> 01:04:25,210
sure somebody somewhere has done that

1557
01:04:29,670 --> 01:04:27,700
calculation about how much we have to

1558
01:04:31,620 --> 01:04:29,680
pay attention to the impurities but

1559
01:04:33,480 --> 01:04:31,630
that's the rough sort of description of

1560
01:04:36,180 --> 01:04:33,490
it now the magnetic field and the

1561
01:04:39,090 --> 01:04:36,190
atmosphere I want to make sure that we

1562
01:04:41,010 --> 01:04:39,100
get the picture right so picture this

1563
01:04:43,770 --> 01:04:41,020

liquid metallic hydrogen under very high

1564
01:04:45,300 --> 01:04:43,780
pressure swirling around because there's

1565
01:04:48,120 --> 01:04:45,310
heat coming out of the planet and the

1566
01:04:50,550 --> 01:04:48,130
planet is rotating rapidly so you know

1567
01:04:52,500 --> 01:04:50,560
the heat wants to make things rise right

1568
01:04:54,900 --> 01:04:52,510
you carry the heat out you move material

1569
01:04:57,930 --> 01:04:54,910
around and spin the planet around

1570
01:05:00,720 --> 01:04:57,940
rapidly it doesn't move in a nice smooth

1571
01:05:03,000 --> 01:05:00,730
easy pattern you get shear so you have

1572
01:05:04,800 --> 01:05:03,010
stuff stirred up that's generating a

1573
01:05:07,740 --> 01:05:04,810
magnetic field that's got to be the bulk

1574
01:05:10,440 --> 01:05:07,750
of the magnetic field from Jupiter but

1575
01:05:12,090 --> 01:05:10,450
our measurements show that the magnetic

1576
01:05:14,730 --> 01:05:12,100
field is more complicated than we

1577
01:05:17,760 --> 01:05:14,740
thought it should be based on that so

1578
01:05:22,140 --> 01:05:17,770
one possible answer is by no means sure

1579
01:05:26,360 --> 01:05:22,150
is that higher up just above that

1580
01:05:28,800 --> 01:05:26,370
metallic hydrogen layer where the

1581
01:05:31,320 --> 01:05:28,810
hydrogen is compressed but not enough to

1582
01:05:34,080 --> 01:05:31,330
make liquid metallic hydrogen that maybe

1583
01:05:35,700 --> 01:05:34,090
that conducts a look electricity a

1584
01:05:38,820 --> 01:05:35,710
little bit and we know that if you

1585
01:05:41,600 --> 01:05:38,830
squeeze hydrogen gas enough you can

1586
01:05:44,910 --> 01:05:41,610
pressure ionize it you can have those

1587
01:05:46,500 --> 01:05:44,920
hydrogen atoms smashing into each other

1588
01:05:48,780 --> 01:05:46,510

so much because of the high pressure

1589
01:05:51,090 --> 01:05:48,790
that every once in a while an electron

1590
01:05:52,920 --> 01:05:51,100
gets stripped off and so you have a

1591
01:05:55,800 --> 01:05:52,930
little bit of conductivity some of the

1592
01:05:57,440 --> 01:05:55,810
Mariah's instead of atoms if you do

1593
01:06:00,660 --> 01:05:57,450
something like that conduct electricity

1594
01:06:02,850 --> 01:06:00,670
there and it's all moving around that

1595
01:06:05,790 --> 01:06:02,860
could affect the magnetic field now the

1596
01:06:07,620 --> 01:06:05,800
way a dynamo works yes the magnetic

1597
01:06:10,650 --> 01:06:07,630
field is definitely interacting with the

1598
01:06:12,180 --> 01:06:10,660
motion of the liquid so it's not you

1599
01:06:13,950 --> 01:06:12,190
make the liquid move around and produce

1600
01:06:15,810 --> 01:06:13,960
a magnetic field and voila you get a

1601
01:06:18,150 --> 01:06:15,820
field from whatever the liquid was doing

1602
01:06:19,770 --> 01:06:18,160
it's you make the liquid move around it

1603
01:06:22,110 --> 01:06:19,780
produces a magnetic field that affects

1604
01:06:23,850 --> 01:06:22,120
the way the liquid is moving makes it

1605
01:06:26,070 --> 01:06:23,860
move in a different way that affects the

1606
01:06:29,920 --> 01:06:26,080
magnetic field and you get this process

1607
01:06:32,680 --> 01:06:29,930
that's much more complicated

1608
01:06:34,329 --> 01:06:32,690
but in which actually the motion of the

1609
01:06:36,549 --> 01:06:34,339
liquid can generate a magnetic field

1610
01:06:38,859 --> 01:06:36,559
that causes it to move in that way some

1611
01:06:42,400 --> 01:06:38,869
more and makes a stronger magnetic field

1612
01:06:45,760 --> 01:06:42,410
that's how a dynamo works we think so

1613
01:06:47,170 --> 01:06:45,770

it's it's not simple but yeah there's

1614
01:06:49,270 --> 01:06:47,180
definitely an interaction between the

1615
01:06:52,270 --> 01:06:49,280
motion of the fluid and the magnetic

1616
01:06:54,599 --> 01:06:52,280
field that it generates now on top of

1617
01:06:57,069 --> 01:06:54,609
that if I look at the upper atmosphere

1618
01:07:04,630 --> 01:06:57,079
if you remember that picture with the

1619
01:07:09,849 --> 01:07:04,640
belts and zones the movie this one it's

1620
01:07:12,970 --> 01:07:09,859
not playing I can't tell if that's

1621
01:07:16,120 --> 01:07:12,980
starting to belong there we go

1622
01:07:18,549 --> 01:07:16,130
so if you remember that we have this

1623
01:07:21,849 --> 01:07:18,559
speculation and it's only speculation at

1624
01:07:24,609 --> 01:07:21,859
this point that the fact that those

1625
01:07:26,710 --> 01:07:24,619
belts and zones are 3,000 kilometers

1626
01:07:28,690 --> 01:07:26,720
deep might have something to do with

1627
01:07:30,309 --> 01:07:28,700
getting deep enough to where the

1628
01:07:33,520 --> 01:07:30,319
pressure makes a little bit of

1629
01:07:35,920 --> 01:07:33,530
conductivity and perhaps below that

1630
01:07:37,780 --> 01:07:35,930
where the the gas conducts electricity a

1631
01:07:39,370 --> 01:07:37,790
little better maybe the magnetic field

1632
01:07:42,280 --> 01:07:39,380
holds it and stops the belts and zones

1633
01:07:44,230 --> 01:07:42,290
from going any deeper speculation at

1634
01:07:46,390 --> 01:07:44,240
this point the the main thing is we can

1635
01:07:47,890 --> 01:07:46,400
tell from the measurement about how deep

1636
01:07:50,349 --> 01:07:47,900
they go and we can tell from the

1637
01:07:52,780 --> 01:07:50,359
measurement that below that the planet

1638
01:07:55,359 --> 01:07:52,790

rotates as a solid bar the body and then

1639
01:07:58,059 --> 01:07:55,369
anybody who thinks about planets can try

1640
01:07:59,920 --> 01:07:58,069
to figure out why it does that and of

1641
01:08:02,859 --> 01:07:59,930
course we have lots of people working

1642
01:08:05,170 --> 01:08:02,869
hard on that even as we speak they're

1643
01:08:06,970 --> 01:08:05,180
probably at home you know thinking about

1644
01:08:08,890 --> 01:08:06,980
things and working on their computer

1645
01:08:11,170 --> 01:08:08,900
models okay

1646
01:08:13,390 --> 01:08:11,180
did that cover the what you're asking

1647
01:08:14,890 --> 01:08:13,400
thank you very much like I obviously

1648
01:08:17,050 --> 01:08:14,900
have other questions but I think that's

1649
01:08:18,280 --> 01:08:17,060
enough well you're welcome to go to the

1650
01:08:19,650 --> 01:08:18,290
end of the line and come back and ask

1651
01:08:26,590 --> 01:08:19,660
your question thank you

1652
01:08:28,269 --> 01:08:26,600
after those very simple I just want to

1653
01:08:30,669 --> 01:08:28,279
know what would you say would be a

1654
01:08:33,519 --> 01:08:30,679
difference from the hot Jupiter the new

1655
01:08:35,470 --> 01:08:33,529
Jupiter would with those all that

1656
01:08:37,180 --> 01:08:35,480
information be different I'm sorry I'm

1657
01:08:40,329 --> 01:08:37,190
save the beginning part again the

1658
01:08:43,330 --> 01:08:40,339
difference between hot Jupiters oh you

1659
01:08:45,970 --> 01:08:43,340
mean like around other stars and arge

1660
01:08:52,660 --> 01:08:45,980
so from the information you just are

1661
01:08:55,080 --> 01:08:52,670
discovering them right so it's a

1662
01:09:00,100 --> 01:08:55,090
trickier question than it sounds and

1663
01:09:05,140 --> 01:09:00,110

that's because in many ways what we know

1664
01:09:07,990 --> 01:09:05,150
about the planets around other stars is

1665
01:09:09,700 --> 01:09:08,000
much more limited but of course we have

1666
01:09:13,030 --> 01:09:09,710
lots of them instead of just the only

1667
01:09:14,710 --> 01:09:13,040
one example we have here I know a lot of

1668
01:09:16,180 --> 01:09:14,720
people there's a bus that they're trying

1669
01:09:20,770 --> 01:09:16,190
to catch is why we have a bunch of

1670
01:09:24,100 --> 01:09:20,780
people leaving at the moment so we don't

1671
01:09:28,030 --> 01:09:24,110
really have that comparison yet our

1672
01:09:31,290 --> 01:09:28,040
guess would be that the one planet giant

1673
01:09:34,060 --> 01:09:31,300
planet that we have jupiter is

1674
01:09:37,630 --> 01:09:34,070
presumably sort of typical for what

1675
01:09:39,610 --> 01:09:37,640
planets that size look like but we only

1676
01:09:43,060 --> 01:09:39,620
have the one we don't have 50 of them to

1677
01:09:45,010 --> 01:09:43,070
look at and if you look at the planets

1678
01:09:47,050 --> 01:09:45,020
around other stars that we've discovered

1679
01:09:48,550 --> 01:09:47,060
there's all these biases about how you

1680
01:09:51,700 --> 01:09:48,560
discover them makes it easier to

1681
01:09:54,670 --> 01:09:51,710
discover big ones close to the star and

1682
01:09:59,020 --> 01:09:54,680
so forth I will say that until people

1683
01:10:01,570 --> 01:09:59,030
started finding exoplanets like that no

1684
01:10:04,870 --> 01:10:01,580
one really expected to find giant

1685
01:10:06,640 --> 01:10:04,880
planets that close to a star so the

1686
01:10:09,580 --> 01:10:06,650
model of how two stars how two solar

1687
01:10:12,580 --> 01:10:09,590
systems form still has a lot of work to

1688
01:10:15,070 --> 01:10:12,590

go on it to understand we think it has

1689
01:10:17,920 --> 01:10:15,080
something to do with planets forming

1690
01:10:19,870 --> 01:10:17,930
farther from the star and drifting in

1691
01:10:21,970 --> 01:10:19,880
where does they gobble up the material

1692
01:10:25,240 --> 01:10:21,980
that makes up the the early solar system

1693
01:10:27,960 --> 01:10:25,250
and in fact we think perhaps that

1694
01:10:31,120 --> 01:10:27,970
Jupiter formed further from the Sun

1695
01:10:33,580 --> 01:10:31,130
drifted inward gobbling up stuff on the

1696
01:10:36,070 --> 01:10:33,590
way and in the process

1697
01:10:39,040 --> 01:10:36,080
disturb the orbits of what now our

1698
01:10:41,290 --> 01:10:39,050
Neptune and Saturn and kicked them out

1699
01:10:42,820 --> 01:10:41,300
into the outer solar system and maybe

1700
01:10:45,100 --> 01:10:42,830
even stirred up the things that

1701
01:10:47,200 --> 01:10:45,110
eventually became the Earth and Mars and

1702
01:10:49,120 --> 01:10:47,210
all the small planets we'll learn more

1703
01:10:51,070 --> 01:10:49,130
about that as we finally get the water

1704
01:10:52,860 --> 01:10:51,080
content which is going to come as

1705
01:10:55,480 --> 01:10:52,870
we understand the atmosphere better

1706
01:10:57,910 --> 01:10:55,490
that'll tell us a lot about whether

1707
01:11:01,330 --> 01:10:57,920
Jupiter moved or whether it formed where

1708
01:11:02,680 --> 01:11:01,340
it is now oh and then also the the Jade

1709
01:11:05,230 --> 01:11:02,690
I think that's what you were referring

1710
01:11:07,900 --> 01:11:05,240
to for the middle part of where it was

1711
01:11:12,910 --> 01:11:07,910
measuring I think that's what it's

1712
01:11:15,070 --> 01:11:12,920
called the Jovian so there's we have two

1713
01:11:16,930 --> 01:11:15,080

instruments on the spacecraft that

1714
01:11:18,340 --> 01:11:16,940
measure the particles that are hitting

1715
01:11:23,220 --> 01:11:18,350
the the spacecraft

1716
01:11:25,570 --> 01:11:23,230
there's the Jade which is Jovian auroral

1717
01:11:26,050 --> 01:11:25,580
distributions experiment or something

1718
01:11:28,900 --> 01:11:26,060
like that

1719
01:11:31,150 --> 01:11:28,910
and that measures the relatively low

1720
01:11:34,270 --> 01:11:31,160
energy charged particles and then

1721
01:11:37,000 --> 01:11:34,280
there's Jedi which I won't try to

1722
01:11:39,430 --> 01:11:37,010
remember the acronym but it oh well

1723
01:11:44,740 --> 01:11:39,440
you're right it was on one of my my very

1724
01:11:48,400 --> 01:11:44,750
first slide there you go and so Jedi is

1725
01:11:50,680 --> 01:11:48,410
the higher energy particles it's hard to

1726
01:11:55,150 --> 01:11:50,690
get through all of these slides

1727
01:11:57,310 --> 01:11:55,160
backwards there we go okay good so Jedi

1728
01:11:59,680 --> 01:11:57,320
is Jupiter energetic particle detector

1729
01:12:04,330 --> 01:11:59,690
of ions it must be ions because that's

1730
01:12:07,000 --> 01:12:04,340
the eye anyway so we have to measure a

1731
01:12:09,040 --> 01:12:07,010
full range of energetic particles and

1732
01:12:10,690 --> 01:12:09,050
then they work together right because

1733
01:12:13,300 --> 01:12:10,700
the particles don't know whether they're

1734
01:12:15,100 --> 01:12:13,310
energetic or not energetic and in terms

1735
01:12:17,500 --> 01:12:15,110
of distributions it's not like they come

1736
01:12:19,930 --> 01:12:17,510
in nice little bins so you measure that

1737
01:12:22,000 --> 01:12:19,940
you measure the the plasma waves that

1738
01:12:24,700 --> 01:12:22,010

are going through so you see magnetic

1739
01:12:26,770 --> 01:12:24,710
and electric fields you you measure the

1740
01:12:28,420 --> 01:12:26,780
light from when those particles hit the

1741
01:12:30,370 --> 01:12:28,430
atmosphere so that's the ultraviolet and

1742
01:12:32,380 --> 01:12:30,380
the infrared cameras you measure the

1743
01:12:33,580 --> 01:12:32,390
radio waves given off by the particles

1744
01:12:35,710 --> 01:12:33,590
we can do that when the microwave

1745
01:12:37,780 --> 01:12:35,720
radiometer we measure the magnetic field

1746
01:12:39,790 --> 01:12:37,790
that organizes all of it put all that

1747
01:12:42,580 --> 01:12:39,800
together in a big picture and that's how

1748
01:12:44,050 --> 01:12:42,590
we understand the magnetosphere so it's

1749
01:12:46,510 --> 01:12:44,060
all of those instruments working

1750
01:12:48,940 --> 01:12:46,520
together as a team to really understand

1751
01:12:51,330 --> 01:12:48,950
the picture well that's awesome thank

1752
01:12:53,980 --> 01:12:51,340
you thank you

1753
01:12:55,560 --> 01:12:53,990
all right I have a very quick question

1754
01:12:58,630 --> 01:12:55,570
regarding the Cyclones

1755
01:13:00,700 --> 01:12:58,640
so I know we previously went over that

1756
01:13:03,010 --> 01:13:00,710
on the same side the Cyclones next to

1757
01:13:05,110 --> 01:13:03,020
each other they're moving the same

1758
01:13:08,200 --> 01:13:05,120
correction however I was wondering if

1759
01:13:11,260 --> 01:13:08,210
the cyclone groups on the north pole are

1760
01:13:14,260 --> 01:13:11,270
moving the same directions as those on

1761
01:13:17,170 --> 01:13:14,270
the South Pole and if so what is the

1762
01:13:20,350 --> 01:13:17,180
popular the most popular theories that

1763
01:13:22,360 --> 01:13:20,360

we have come up with or given if is

1764
01:13:23,830 --> 01:13:22,370
speculation that would be good to all

1765
01:13:26,350 --> 01:13:23,840
right so let's look at the pictures and

1766
01:13:28,810 --> 01:13:26,360
we can actually answer that question so

1767
01:13:31,570 --> 01:13:28,820
here's the South Pole so I'm looking at

1768
01:13:34,260 --> 01:13:31,580
it from the south and you can see the

1769
01:13:37,480 --> 01:13:34,270
spiral goes around that way right yes

1770
01:13:39,010 --> 01:13:37,490
here's the North Pole I'm looking at it

1771
01:13:44,490 --> 01:13:39,020
from the north and you can see the

1772
01:13:46,600 --> 01:13:44,500
spiral goes around the other way okay so

1773
01:13:48,100 --> 01:13:46,610
you know whether there whether that's

1774
01:13:50,890 --> 01:13:48,110
the same direction or opposite direction

1775
01:13:52,900 --> 01:13:50,900
depends on you know the viewpoint right

1776
01:13:55,840 --> 01:13:52,910
but you can see which directions there

1777
01:13:57,400 --> 01:13:55,850
they're spinning that way and then since

1778
01:13:59,950 --> 01:13:57,410
all of these are doing the same thing

1779
01:14:01,000 --> 01:13:59,960
then that's why it's a problem if

1780
01:14:03,310 --> 01:14:01,010
they're all spending the same direction

1781
01:14:05,680 --> 01:14:03,320
and rubbing on each other somehow they

1782
01:14:07,480 --> 01:14:05,690
have to you know so something has to

1783
01:14:09,370 --> 01:14:07,490
supply energy to keep them rubbing on

1784
01:14:11,320 --> 01:14:09,380
each other or something has to give them

1785
01:14:13,960 --> 01:14:11,330
you know a way to spin next to each

1786
01:14:16,030 --> 01:14:13,970
other and not destroy each other it's

1787
01:14:18,970 --> 01:14:16,040
also true that if you take a rotating

1788
01:14:21,370 --> 01:14:18,980

planet and you put a cyclone on it and

1789
01:14:23,860 --> 01:14:21,380
say what does it do

1790
01:14:26,710 --> 01:14:23,870
what you would expect actually is the

1791
01:14:28,330 --> 01:14:26,720
cyclone will drift up towards the North

1792
01:14:29,860 --> 01:14:28,340
Pole or if it's on the southern

1793
01:14:32,590 --> 01:14:29,870
atmosphere spending the right way to do

1794
01:14:36,130 --> 01:14:32,600
that drift down towards the South Pole

1795
01:14:37,480 --> 01:14:36,140
because if you imagine you know you're

1796
01:14:39,900 --> 01:14:37,490
on Jupiter you're a little bit north of

1797
01:14:43,420 --> 01:14:39,910
the equator and you're spinning around

1798
01:14:48,490 --> 01:14:43,430
well the whole planet is rotating the

1799
01:14:50,830 --> 01:14:48,500
part that's that's closer to the equator

1800
01:14:53,410 --> 01:14:50,840
has further to go all the way around the

1801
01:14:56,440 --> 01:14:53,420
planet than the part that's north of the

1802
01:14:59,530 --> 01:14:56,450
Equator so if I come around in my

1803
01:15:02,620 --> 01:14:59,540
cyclone and I'm going north then I'm

1804
01:15:04,680 --> 01:15:02,630
shifting speeds if I come around the

1805
01:15:07,660 --> 01:15:04,690
other way that I'm shifting speeds

1806
01:15:09,400 --> 01:15:07,670
downward right so if you work out all

1807
01:15:11,650 --> 01:15:09,410
the you know add up all the speeds and

1808
01:15:15,010 --> 01:15:11,660
say what does the air do you wind up

1809
01:15:17,150 --> 01:15:15,020
with a little bit more speed heading

1810
01:15:18,980 --> 01:15:17,160
north than heading south if

1811
01:15:21,200 --> 01:15:18,990
cycles spinning the right direction to

1812
01:15:24,680 --> 01:15:21,210
be a cyclone so you expect the cyclones

1813
01:15:26,120 --> 01:15:24,690

to drift up to the north that of course

1814
01:15:27,620 --> 01:15:26,130
doesn't explain everything you have to

1815
01:15:28,280 --> 01:15:27,630
say well way to the Cyclones come from

1816
01:15:30,380 --> 01:15:28,290
in the first place

1817
01:15:32,090 --> 01:15:30,390
and why do they last long enough to spin

1818
01:15:33,470 --> 01:15:32,100
up to the north and why do they last

1819
01:15:36,020 --> 01:15:33,480
long enough when they're all butted up

1820
01:15:38,420 --> 01:15:36,030
against each other so that we see them

1821
01:15:41,390 --> 01:15:38,430
you know for two years so far and not

1822
01:15:43,820 --> 01:15:41,400
much change but at least a little piece

1823
01:15:45,740 --> 01:15:43,830
of that puzzle is explained by just if I

1824
01:15:47,720 --> 01:15:45,750
make a cyclone and I don't have anything

1825
01:15:49,550 --> 01:15:47,730
to stop it there's no ground for it to

1826
01:15:51,830 --> 01:15:49,560
run into it's kind of just gradually

1827
01:15:58,700 --> 01:15:51,840
drift north with north or even pile up

1828
01:16:01,460 --> 01:15:58,710
at the North Pole well has anybody made

1829
01:16:04,250 --> 01:16:01,470
any prediction when exactly that has

1830
01:16:07,010 --> 01:16:04,260
started and will it ever stop or is just

1831
01:16:09,620 --> 01:16:07,020
constantly gonna keep going or nobody

1832
01:16:12,860 --> 01:16:09,630
has ever made any sort of predictions or

1833
01:16:14,690 --> 01:16:12,870
studies yet well it's pretty new I mean

1834
01:16:16,790 --> 01:16:14,700
we've been there for less than two years

1835
01:16:19,490 --> 01:16:16,800
and this was a big surprise to everybody

1836
01:16:21,380 --> 01:16:19,500
in the first place but one of the things

1837
01:16:24,080 --> 01:16:21,390
we're doing is watching these cyclones

1838
01:16:26,690 --> 01:16:24,090

really carefully to try to see how they

1839
01:16:28,880 --> 01:16:26,700
change so you keep coming back and you

1840
01:16:31,730 --> 01:16:28,890
look at those five cyclones around the

1841
01:16:34,730 --> 01:16:31,740
South Pole and they're always there

1842
01:16:37,160 --> 01:16:34,740
every pass but if you take a really good

1843
01:16:38,930 --> 01:16:37,170
look at the images and compare their

1844
01:16:41,060 --> 01:16:38,940
shifting a little bit they're not just

1845
01:16:42,170 --> 01:16:41,070
rotating in place they're moving a

1846
01:16:44,450 --> 01:16:42,180
little bit so we're trying to start

1847
01:16:46,670 --> 01:16:44,460
tracking them and use that to try to

1848
01:16:48,560 --> 01:16:46,680
understand how long do they really last

1849
01:16:51,170 --> 01:16:48,570
and what do they do and how do they move

1850
01:16:53,630 --> 01:16:51,180
and all of that stuff do you have a

1851
01:16:57,050 --> 01:16:53,640
specific website that's dedicated to

1852
01:17:00,580 --> 01:16:57,060
this that I can sort of follow to see

1853
01:17:05,000 --> 01:17:00,590
they're tracking and all those status I

1854
01:17:09,080 --> 01:17:05,010
don't think so I think your best bet for

1855
01:17:11,600 --> 01:17:09,090
that is to keep on eye on NASA's website

1856
01:17:14,870 --> 01:17:11,610
for Juno if you look at you know

1857
01:17:19,400 --> 01:17:14,880
nasa.gov slash Juno or on mission Juno

1858
01:17:21,530 --> 01:17:19,410
dot s WRI which is a more sort of public

1859
01:17:24,470 --> 01:17:21,540
friendly version they're both fairly

1860
01:17:25,610 --> 01:17:24,480
friendly but that's that's the one

1861
01:17:27,050 --> 01:17:25,620
that's also got all that you know camp

1862
01:17:29,280 --> 01:17:27,060
stuff I'm switching through to get to

1863
01:17:30,960 --> 01:17:29,290

the websites because

1864
01:17:33,270 --> 01:17:30,970
telling you the name is probably not

1865
01:17:35,930 --> 01:17:33,280
gonna be easy to remember but you can

1866
01:17:38,460 --> 01:17:35,940
write it down or find in it online

1867
01:17:41,190 --> 01:17:38,470
probably the place to do is follow there

1868
01:17:43,500 --> 01:17:41,200
and of course it's will publish things

1869
01:17:47,430 --> 01:17:43,510
in the scientific literature but that's

1870
01:17:48,900 --> 01:17:47,440
gonna be a while good question though

1871
01:17:52,290 --> 01:17:48,910
maybe we should think about whether

1872
01:17:54,570 --> 01:17:52,300
there's a way to you know take the

1873
01:17:56,220 --> 01:17:54,580
different scientific questions and put

1874
01:17:58,890 --> 01:17:56,230
them out there and let people follow the

1875
01:18:01,350 --> 01:17:58,900
story a little better it would be great

1876
01:18:03,630 --> 01:18:01,360
if everybody can take votes on like

1877
01:18:06,240 --> 01:18:03,640
which sort of data they want to follow

1878
01:18:08,490 --> 01:18:06,250
and then you can open up like a tab on a

1879
01:18:10,740 --> 01:18:08,500
website just dedicate it to those data

1880
01:18:13,710 --> 01:18:10,750
and constantly updating them every month

1881
01:18:15,180 --> 01:18:13,720
that would be awesome I like the idea

1882
01:18:16,950 --> 01:18:15,190
but I'm also picturing the people who

1883
01:18:18,150 --> 01:18:16,960
would have to do that saying you know we

1884
01:18:24,750 --> 01:18:18,160
don't have anywhere near enough people

1885
01:18:27,720 --> 01:18:24,760
to do that thank you hi I have two

1886
01:18:30,060 --> 01:18:27,730
questions the first is do you think that

1887
01:18:32,280 --> 01:18:30,070
the that there are eight cyclones in the

1888
01:18:34,170 --> 01:18:32,290

North Pole and five at the South Pole

1889
01:18:36,750 --> 01:18:34,180
does that have any anything to do with

1890
01:18:39,360 --> 01:18:36,760
the fact that the magnetic fields seem

1891
01:18:40,979 --> 01:18:39,370
to be more turbulent in the north and my

1892
01:18:42,840 --> 01:18:40,989
second question is that it seems like

1893
01:18:45,900 --> 01:18:42,850
most of the science is coming from the

1894
01:18:48,390 --> 01:18:45,910
flyby period of Juno are we collecting

1895
01:18:52,680 --> 01:18:48,400
any data from when it's like the rest of

1896
01:18:54,320 --> 01:18:52,690
its orbit right okay so about the

1897
01:18:57,300 --> 01:18:54,330
Cyclones of the magnetic field

1898
01:19:00,030 --> 01:18:57,310
yeah it's striking that the planet is

1899
01:19:02,870 --> 01:19:00,040
asymmetric in its magnetic field and in

1900
01:19:08,340 --> 01:19:02,880
its atmosphere and as seen at the top

1901
01:19:11,640 --> 01:19:08,350
and it's gravity signature but it's hard

1902
01:19:15,300 --> 01:19:11,650
to picture how the magnetic field could

1903
01:19:18,390 --> 01:19:15,310
be influencing those cyclones because up

1904
01:19:20,460 --> 01:19:18,400
at the top of the atmosphere we're at

1905
01:19:22,950 --> 01:19:20,470
pressures similar to the pressure here

1906
01:19:25,110 --> 01:19:22,960
in this room the gas doesn't conduct

1907
01:19:27,360 --> 01:19:25,120
electricity very well so it shouldn't be

1908
01:19:30,420 --> 01:19:27,370
affected by the magnetic field much and

1909
01:19:32,810 --> 01:19:30,430
it's got huge amounts of mass moving at

1910
01:19:35,490 --> 01:19:32,820
pretty good velocity since these are

1911
01:19:37,709 --> 01:19:35,500
cyclones right think of you know the

1912
01:19:40,590 --> 01:19:37,719
power in a hurricane here on the earth

1913
01:19:42,090 --> 01:19:40,600

and now you're talking about storms that

1914
01:19:46,650 --> 01:19:42,100
are bigger than the biggest

1915
01:19:48,990 --> 01:19:46,660
hurricane you've ever imagined so nobody

1916
01:19:52,470 --> 01:19:49,000
has yet come up with a mechanism that

1917
01:19:55,070 --> 01:19:52,480
explains that that connects the northern

1918
01:19:58,380 --> 01:19:55,080
the the asymmetry in the magnetic field

1919
01:20:00,540 --> 01:19:58,390
with the asymmetry in the weather not

1920
01:20:02,850 --> 01:20:00,550
saying it's not possible but I haven't

1921
01:20:06,300 --> 01:20:02,860
heard an argument that works or anything

1922
01:20:08,520 --> 01:20:06,310
where the math plays out at all what was

1923
01:20:11,700 --> 01:20:08,530
the other thing you asked with if Juno

1924
01:20:13,170 --> 01:20:11,710
collects like data on the estimates data

1925
01:20:14,460 --> 01:20:13,180
away from peridot we call that part

1926
01:20:17,250 --> 01:20:14,470
where we get really close to Jupiter

1927
01:20:21,000 --> 01:20:17,260
peridot you know near Jupiter para Jove

1928
01:20:23,400 --> 01:20:21,010
and the most important science data in

1929
01:20:25,920 --> 01:20:23,410
general is from peridot as you said from

1930
01:20:27,990 --> 01:20:25,930
within a few hours of our closest

1931
01:20:29,880 --> 01:20:28,000
approach but yeah we don't turn the

1932
01:20:31,650 --> 01:20:29,890
instruments off for 53 days when they're

1933
01:20:34,500 --> 01:20:31,660
out far from Jupiter and there's other

1934
01:20:36,000 --> 01:20:34,510
things we get to measure in particular a

1935
01:20:38,250 --> 01:20:36,010
lot of the fields and particles

1936
01:20:39,750 --> 01:20:38,260
instruments you know get to measure a

1937
01:20:41,940 --> 01:20:39,760
lot of interesting stuff about the

1938
01:20:43,980 --> 01:20:41,950

magnetosphere because Jupiter's magnetic

1939
01:20:47,190 --> 01:20:43,990
field stretches way out there and our

1940
01:20:49,800 --> 01:20:47,200
orbit is big enough that we have why we

1941
01:20:51,960 --> 01:20:49,810
cross lots of interesting regions quite

1942
01:20:54,120 --> 01:20:51,970
far from Jupiter and we do those

1943
01:20:56,400 --> 01:20:54,130
measurements it's not a prime science we

1944
01:20:58,500 --> 01:20:56,410
went there for but it's lots of good

1945
01:21:02,250 --> 01:20:58,510
stuff and we're collecting lots of data

1946
01:21:04,710 --> 01:21:02,260
and the microwave radiometer that does

1947
01:21:06,900 --> 01:21:04,720
those atmospheric measurements the data

1948
01:21:08,850 --> 01:21:06,910
right up next to Jupiter are way more

1949
01:21:11,880 --> 01:21:08,860
valuable than any of the rest of the

1950
01:21:14,580 --> 01:21:11,890
data from that microwave radiometer but

1951
01:21:16,350 --> 01:21:14,590
it doesn't use up a lot of bandwidth to

1952
01:21:19,950 --> 01:21:16,360
send that to the ground we get to learn

1953
01:21:21,900 --> 01:21:19,960
about the radiation belts a little by

1954
01:21:23,730 --> 01:21:21,910
seeing them in the radio and microwave

1955
01:21:26,940 --> 01:21:23,740
radiometers don't like to be turned on

1956
01:21:29,730 --> 01:21:26,950
and off so we just leave it on let it

1957
01:21:32,310 --> 01:21:29,740
run and collect the data and all we do

1958
01:21:34,530 --> 01:21:32,320
is throttle back the data rate a little

1959
01:21:37,230 --> 01:21:34,540
bit when it's away from the planet so we

1960
01:21:38,610 --> 01:21:37,240
won't won't be wasting the communication

1961
01:21:40,920 --> 01:21:38,620
with the ground cuz you can only send so

1962
01:21:43,920 --> 01:21:40,930
much data at a time but we just leave it

1963
01:21:46,740 --> 01:21:43,930

on and I think it's about one-seventh of

1964
01:21:49,140 --> 01:21:46,750
the data rate the whole time just

1965
01:21:53,520 --> 01:21:49,150
because it's safer for it to never turn

1966
01:21:56,980 --> 01:21:53,530
it off thanks sure

1967
01:21:59,830 --> 01:21:56,990
hi I had a question about the

1968
01:22:02,470 --> 01:21:59,840
consistency of the magnetic field

1969
01:22:04,840 --> 01:22:02,480
measurements over multiple years given

1970
01:22:06,700 --> 01:22:04,850
that it's being generated by a fluid

1971
01:22:08,620 --> 01:22:06,710
right it would seem reasonable that

1972
01:22:10,720 --> 01:22:08,630
maybe over the course of multiple years

1973
01:22:12,490 --> 01:22:10,730
that would shift and so the map is

1974
01:22:15,400 --> 01:22:12,500
actually changing and not like a

1975
01:22:19,720 --> 01:22:15,410
consistent map right so we are looking

1976
01:22:22,900 --> 01:22:19,730
for variation in the magnetic field over

1977
01:22:26,800 --> 01:22:22,910
time but you have to remember Jupiter is

1978
01:22:29,820 --> 01:22:26,810
so big that it's really hard for us to

1979
01:22:32,440 --> 01:22:29,830
picture the time scales involved so

1980
01:22:34,180 --> 01:22:32,450
we're gonna be a Jupiter if everything

1981
01:22:35,920 --> 01:22:34,190
goes well and imagine the spacecraft

1982
01:22:37,960 --> 01:22:35,930
lasts for a really long time and we wind

1983
01:22:39,790 --> 01:22:37,970
up doing an extended mission and all of

1984
01:22:42,520 --> 01:22:39,800
that stuff suppose you know everything

1985
01:22:43,720 --> 01:22:42,530
goes perfectly and nASA says sure do

1986
01:22:45,400 --> 01:22:43,730
whatever you want we'll give you lots of

1987
01:22:48,640 --> 01:22:45,410
money and all of that

1988
01:22:52,030 --> 01:22:48,650

maybe the spacecraft would be around for

1989
01:22:55,090 --> 01:22:52,040
another I don't know I'm totally making

1990
01:22:57,100 --> 01:22:55,100
it up but say 10 more years right it's

1991
01:22:58,360 --> 01:22:57,110
not gonna be beyond that because the

1992
01:22:59,070 --> 01:22:58,370
radiation sooner or later is going to

1993
01:23:00,610 --> 01:22:59,080
kill it

1994
01:23:02,200 --> 01:23:00,620
Jupiter's been around for

1995
01:23:06,000 --> 01:23:02,210
four-and-a-half billion years it hasn't

1996
01:23:09,580 --> 01:23:06,010
even finished cooling off yet the the

1997
01:23:13,060 --> 01:23:09,590
motions in the interior you know suppose

1998
01:23:15,400 --> 01:23:13,070
that that dynamo is like shifting like

1999
01:23:17,620 --> 01:23:15,410
crazy on a flash of a time scale on

2000
01:23:22,090 --> 01:23:17,630
Jupiter's timescale that still might be

2001
01:23:24,100 --> 01:23:22,100
500 years so yes we are looking for

2002
01:23:26,920 --> 01:23:24,110
variation in the magnetic field we hope

2003
01:23:28,810 --> 01:23:26,930
that as we get through all our 32 orbits

2004
01:23:31,720 --> 01:23:28,820
and maybe you know extended mission or

2005
01:23:34,210 --> 01:23:31,730
something you go beyond that that we'll

2006
01:23:39,040 --> 01:23:34,220
be able to tell whether the magnetic

2007
01:23:40,600 --> 01:23:39,050
field is varying but given that of

2008
01:23:43,120 --> 01:23:40,610
course to Pater's surprised us a bunch

2009
01:23:46,030 --> 01:23:43,130
don't expect it to be varying on

2010
01:23:47,680 --> 01:23:46,040
timescales of a year or two we expect to

2011
01:23:49,570 --> 01:23:47,690
be able to measure really small

2012
01:23:51,820 --> 01:23:49,580
variations of the magnetic field and say

2013
01:23:56,920 --> 01:23:51,830

yeah I think if you waited a thousand

2014
01:23:59,080 --> 01:23:56,930
years it would do this sure

2015
01:24:00,160 --> 01:23:59,090
perhaps this hasn't been determined yet

2016
01:24:01,900 --> 01:24:00,170
because you got to finish the mission

2017
01:24:05,260 --> 01:24:01,910
and then just alluded to possible

2018
01:24:07,030 --> 01:24:05,270
extended mission but at some point do

2019
01:24:07,240 --> 01:24:07,040
you anticipate that that Juno is going

2020
01:24:14,920 --> 01:24:07,250
to

2021
01:24:16,900 --> 01:24:14,930
yes so right now we're on a plan where

2022
01:24:20,020 --> 01:24:16,910
we do 32 orbits

2023
01:24:22,570 --> 01:24:20,030
32 science orbits so it's a few more you

2024
01:24:23,800 --> 01:24:22,580
know with a spare or two to make sure we

2025
01:24:25,930 --> 01:24:23,810
get all the longitudes and do the

2026
01:24:28,990 --> 01:24:25,940
magnetic map and then at the end of that

2027
01:24:30,700 --> 01:24:29,000
we fire the thrusters so that it dives

2028
01:24:31,990 --> 01:24:30,710
into Jupiter's atmosphere and burns up

2029
01:24:34,300 --> 01:24:32,000
that's the plan

2030
01:24:36,300 --> 01:24:34,310
nobody's we're not even asking for an

2031
01:24:39,310 --> 01:24:36,310
extended mission yet you know that's

2032
01:24:42,940 --> 01:24:39,320
gonna be 2021 by by the time that

2033
01:24:45,250 --> 01:24:42,950
happens but presumably if everything

2034
01:24:47,200 --> 01:24:45,260
works great and we're able to show NASA

2035
01:24:48,850 --> 01:24:47,210
that we can protect Europa without

2036
01:24:51,520 --> 01:24:48,860
destroying the spacecraft right away

2037
01:24:53,680 --> 01:24:51,530
then we would figure something out and

2038
01:24:55,270 --> 01:24:53,690

we need to ask and see if you know

2039
01:24:57,760 --> 01:24:55,280
they're willing to let us operate it

2040
01:25:02,230 --> 01:24:57,770
longer we're in the prime mission we're

2041
01:25:04,210 --> 01:25:02,240
not ready to to work on that and we have

2042
01:25:07,210 --> 01:25:04,220
a requirement to make sure that we don't

2043
01:25:09,100 --> 01:25:07,220
contaminate Europa the simplest and most

2044
01:25:11,680 --> 01:25:09,110
straightforward way to not contaminate

2045
01:25:13,510 --> 01:25:11,690
Europa is to vaporize the spacecraft in

2046
01:25:17,350 --> 01:25:13,520
Jupiter you can come up with more

2047
01:25:18,820 --> 01:25:17,360
complicated things and I'm sure you know

2048
01:25:20,500 --> 01:25:18,830
nobody's gonna want to destroy the

2049
01:25:22,480 --> 01:25:20,510
spacecraft without meaning to I'm sure

2050
01:25:23,590 --> 01:25:22,490
when the time comes if somebody comes up

2051
01:25:25,750 --> 01:25:23,600
with a clever plan

2052
01:25:27,910 --> 01:25:25,760
we'll go are you hey look your rope is

2053
01:25:30,520 --> 01:25:27,920
safe enough let us do this another you

2054
01:25:32,980 --> 01:25:30,530
know so many orbits but right now we're

2055
01:25:35,680 --> 01:25:32,990
on a plan and the plan has it in orbit

2056
01:25:37,230 --> 01:25:35,690
I think it's orbit 36 if I remember

2057
01:25:40,420 --> 01:25:37,240
correctly but something like that

2058
01:25:42,250 --> 01:25:40,430
so after 32 science orbits plus a couple

2059
01:25:43,330 --> 01:25:42,260
of spares plus there were one or two at

2060
01:25:46,230 --> 01:25:43,340
the beginning that weren't science

2061
01:25:49,420 --> 01:25:46,240
orbits will fire the thrusters and

2062
01:25:52,540 --> 01:25:49,430
deorbit and burn it up in Jupiter which

2063
01:25:55,450 --> 01:25:52,550

is essentially what Cassini did and as

2064
01:25:58,210 --> 01:25:55,460
you know Cassini did you know extended

2065
01:26:00,520 --> 01:25:58,220
extended extended missions until finally

2066
01:26:01,860 --> 01:26:00,530
they had to you know give up and say

2067
01:26:03,910 --> 01:26:01,870
okay we can't do this anymore

2068
01:26:11,290 --> 01:26:03,920
we're gonna run out of fuel and we have

2069
01:26:13,980 --> 01:26:11,300
to protect Enceladus so the the

2070
01:26:19,450 --> 01:26:13,990
thrusters are just gas we had a we had

2071
01:26:20,560 --> 01:26:19,460
hydrazine and an oxidizer to fire the

2072
01:26:24,460 --> 01:26:20,570
main engine

2073
01:26:27,280 --> 01:26:24,470
the thrusters that control the attitude

2074
01:26:29,290 --> 01:26:27,290
and shape the orbit now are just blow

2075
01:26:32,470 --> 01:26:29,300
little gas out from the fact that the

2076
01:26:34,960 --> 01:26:32,480
tanks are pressurized and that's the

2077
01:26:36,550 --> 01:26:34,970
limiting factor for fuel well the only

2078
01:26:38,680 --> 01:26:36,560
factor for life time might very well

2079
01:26:41,320 --> 01:26:38,690
turn out to be radiation damage we

2080
01:26:43,210 --> 01:26:41,330
haven't seen any significant radiation

2081
01:26:45,880 --> 01:26:43,220
damage yet but there's a long mission to

2082
01:26:47,650 --> 01:26:45,890
go but that's the kind of thing that

2083
01:26:52,380 --> 01:26:47,660
probably limits the technical lifetime

2084
01:26:55,420 --> 01:26:52,390
and then of course you know we're at the

2085
01:26:57,070 --> 01:26:55,430
discretion of Congress and acid to

2086
01:26:59,140 --> 01:26:57,080
decide whether they want to keep paying

2087
01:27:00,370 --> 01:26:59,150
to make this happen if we got to the

2088
01:27:02,140 --> 01:27:00,380

point where we weren't getting great

2089
01:27:04,450 --> 01:27:02,150
science or wasn't worth the money then

2090
01:27:10,230 --> 01:27:04,460
they might that could also be a limiting

2091
01:27:13,720 --> 01:27:10,240
factor looking in the two spacecraft

2092
01:27:18,220 --> 01:27:13,730
version and you know version was

2093
01:27:22,600 --> 01:27:18,230
launched in 1977 Jonah about three

2094
01:27:25,600 --> 01:27:22,610
decades or more more later and with the

2095
01:27:29,650 --> 01:27:25,610
limited capability especially with the

2096
01:27:35,710 --> 01:27:29,660
computer we had that browser now genome

2097
01:27:38,130 --> 01:27:35,720
is much more version just flew by and we

2098
01:27:41,410 --> 01:27:38,140
learned a lot about Jupiter from them

2099
01:27:47,320 --> 01:27:41,420
can you just briefly tell me in those

2100
01:27:50,350 --> 01:27:47,330
three decades what we learned we have we

2101
01:27:55,380 --> 01:27:50,360
had also Galileo in between I'm sure

2102
01:28:01,120 --> 01:27:57,550
interesting thing that I see the two

2103
01:28:04,390 --> 01:28:01,130
spacecraft next to each other well I do

2104
01:28:06,070 --> 01:28:04,400
want to point out that you know that's a

2105
01:28:11,110 --> 01:28:06,080
full scale model and that's a one-fifth

2106
01:28:15,430 --> 01:28:11,120
scale model but but the way I would

2107
01:28:19,180 --> 01:28:15,440
think of it is big picture we explore

2108
01:28:21,070 --> 01:28:19,190
our solar system first with let's just

2109
01:28:23,230 --> 01:28:21,080
get to the planet and see what we can

2110
01:28:25,810 --> 01:28:23,240
learn and you learn a lot from the very

2111
01:28:27,550 --> 01:28:25,820
first flyby and so Voyager was about

2112
01:28:29,800 --> 01:28:27,560
that was about getting from one planet

2113
01:28:31,690 --> 01:28:29,810

to the next and learning an enormous

2114
01:28:32,890 --> 01:28:31,700
amount of stuff because no one had ever

2115
01:28:37,120 --> 01:28:32,900
been there before and every

2116
01:28:38,860 --> 01:28:37,130
was brand-new Galileo was now we've

2117
01:28:40,899 --> 01:28:38,870
learned something about Jupiter we know

2118
01:28:43,030 --> 01:28:40,909
what questions to ask we know what the

2119
01:28:45,640 --> 01:28:43,040
spacecraft has to be able to do to

2120
01:28:48,640 --> 01:28:45,650
survive let's go put something in orbit

2121
01:28:51,160 --> 01:28:48,650
and study the Jovian system so it's

2122
01:28:53,169 --> 01:28:51,170
studied the whole system right the moons

2123
01:28:55,510 --> 01:28:53,179
of Jupiter as well as Jupiter itself

2124
01:28:58,080 --> 01:28:55,520
learn about the magnetic field and to

2125
01:29:03,880 --> 01:28:58,090
make the magneto sphere and all of that

2126
01:29:05,560 --> 01:29:03,890
and then after Galileo and dropped it

2127
01:29:07,120 --> 01:29:05,570
dropped a probe into Jupiter and learned

2128
01:29:08,770 --> 01:29:07,130
a little bit about the atmosphere and

2129
01:29:10,270 --> 01:29:08,780
one of the things we learned one of the

2130
01:29:14,620 --> 01:29:10,280
key things we learned from the Galileo

2131
01:29:16,390 --> 01:29:14,630
probe was that 20 bars 20 going down to

2132
01:29:19,479 --> 01:29:16,400
a pressure of 20 times the pressure here

2133
01:29:22,330 --> 01:29:19,489
on the earth wasn't enough to get to

2134
01:29:23,590 --> 01:29:22,340
where the water was well mixed so people

2135
01:29:25,720 --> 01:29:23,600
thought they were going to measure the

2136
01:29:28,300 --> 01:29:25,730
water content the global water content

2137
01:29:30,490 --> 01:29:28,310
of Jupiter with the Galileo probe and

2138
01:29:31,899 --> 01:29:30,500

then what we found is we measured the

2139
01:29:34,180 --> 01:29:31,909
water the probe did everything it was

2140
01:29:35,260 --> 01:29:34,190
supposed to do but Jupiter was more

2141
01:29:40,050 --> 01:29:35,270
complicated than that

2142
01:29:42,250 --> 01:29:40,060
and it found big surprises it found the

2143
01:29:44,860 --> 01:29:42,260
composition of Jupiter had these heavier

2144
01:29:46,750 --> 01:29:44,870
elements besides hydrogen and helium and

2145
01:29:49,479 --> 01:29:46,760
like three or four times what they were

2146
01:29:51,910 --> 01:29:49,489
expected to be so it sort of matched the

2147
01:29:55,149 --> 01:29:51,920
proportions in the Sun if you took an

2148
01:29:58,479 --> 01:29:55,159
element divided how much of carbon there

2149
01:30:00,520 --> 01:29:58,489
was divided by how much hydrogen there

2150
01:30:02,439 --> 01:30:00,530
was compare that with the ratio in the

2151
01:30:03,970 --> 01:30:02,449
Sun everything was off by a factor of

2152
01:30:06,160 --> 01:30:03,980
three or four there was more of the

2153
01:30:08,260 --> 01:30:06,170
heavier stuff except for water were

2154
01:30:11,050 --> 01:30:08,270
found hardly any water so that was a big

2155
01:30:13,510 --> 01:30:11,060
mystery it was one of the key reasons we

2156
01:30:15,939 --> 01:30:13,520
sent Juno there was to respond to that

2157
01:30:18,280 --> 01:30:15,949
mystery and try to measure the water try

2158
01:30:21,430 --> 01:30:18,290
to see the greater complications and do

2159
01:30:23,380 --> 01:30:21,440
a more specific measurement so Juno

2160
01:30:26,979 --> 01:30:23,390
doesn't try to study the whole Jovian

2161
01:30:30,430 --> 01:30:26,989
system it doesn't try to study multiple

2162
01:30:32,680 --> 01:30:30,440
planets it tries to study Jupiter and

2163
01:30:35,830 --> 01:30:32,690

specific aspects of Jupiter that we now

2164
01:30:37,959 --> 01:30:35,840
know to ask questions about and get into

2165
01:30:40,630 --> 01:30:37,969
much greater detail so you go from a

2166
01:30:43,330 --> 01:30:40,640
flyby that's gonna try to study multiple

2167
01:30:44,570 --> 01:30:43,340
planets and learn the big broad-brush

2168
01:30:49,550 --> 01:30:44,580
stuff that nobody

2169
01:30:51,440 --> 01:30:49,560
yet and do raw exploration to an orbiter

2170
01:30:54,410 --> 01:30:51,450
that's gonna stay in the equatorial

2171
01:30:57,020 --> 01:30:54,420
plane and study the whole system so not

2172
01:30:59,690 --> 01:30:57,030
multiple planets just Jupiter but learn

2173
01:31:03,050 --> 01:30:59,700
all kinds of wide variety of different

2174
01:31:05,060 --> 01:31:03,060
things about Jupiter - a spacecraft like

2175
01:31:08,300 --> 01:31:05,070
Juno that's focused on particular

2176
01:31:10,670 --> 01:31:08,310
questions and study particular things

2177
01:31:12,950 --> 01:31:10,680
about Jupiter that had never been

2178
01:31:15,110 --> 01:31:12,960
studied before and I hope there will be

2179
01:31:18,170 --> 01:31:15,120
eventually a next mission that we'll go

2180
01:31:20,900 --> 01:31:18,180
and study perhaps Europa which is a very

2181
01:31:23,210 --> 01:31:20,910
interesting moon of Jupiter and has a

2182
01:31:26,060 --> 01:31:23,220
liquid water ice ocean and is a place we

2183
01:31:29,420 --> 01:31:26,070
can look for life or any other aspect of

2184
01:31:31,760 --> 01:31:29,430
the Jovian system where we have more

2185
01:31:33,640 --> 01:31:31,770
specific more detailed questions so I

2186
01:31:36,710 --> 01:31:33,650
see those three spacecraft as a

2187
01:31:38,900 --> 01:31:36,720
progression in the level of detail we

2188
01:31:40,820 --> 01:31:38,910

look at and the kinds of question we

2189
01:31:42,620 --> 01:31:40,830
answer and that happens at all the other

2190
01:31:46,520 --> 01:31:42,630
planets in the solar system as well

2191
01:31:48,980 --> 01:31:46,530
we just recently on planetary timescales

2192
01:31:53,210 --> 01:31:48,990
had the New Horizons mission fly by

2193
01:31:56,540 --> 01:31:53,220
Pluto and do that first exploration of

2194
01:31:58,310 --> 01:31:56,550
Pluto I hope some time maybe in my

2195
01:32:00,920 --> 01:31:58,320
lifetime or the lifetime of some of the

2196
01:32:03,040 --> 01:32:00,930
people here will have an orbiter get to

2197
01:32:05,330 --> 01:32:03,050
Pluto and do the more detailed study

2198
01:32:07,820 --> 01:32:05,340
using the information that they learned

2199
01:32:15,380 --> 01:32:07,830
in that flyby so it's it's that same

2200
01:32:18,710 --> 01:32:15,390
progression I guess we're a couple of

2201
01:32:21,740 --> 01:32:18,720
questions from the web so somebody sent

2202
01:32:24,680 --> 01:32:21,750
in why does the Great Red Spot get

2203
01:32:27,380 --> 01:32:24,690
colder below the surface and how does

2204
01:32:30,920 --> 01:32:27,390
adiabatic cooling work if warm at the

2205
01:32:33,290 --> 01:32:30,930
top and cool in the middle and I get to

2206
01:32:36,020 --> 01:32:33,300
say my favorite answer which is not only

2207
01:32:39,920 --> 01:32:36,030
I don't know but nobody knows but

2208
01:32:42,080 --> 01:32:39,930
there's speculation and if you look at

2209
01:32:44,060 --> 01:32:42,090
scientific conferences and at some of

2210
01:32:46,400 --> 01:32:44,070
the papers that are coming out people

2211
01:32:49,720 --> 01:32:46,410
are starting to come up with ideas for

2212
01:32:52,610 --> 01:32:49,730
that so you know watch this space and

2213
01:32:55,760 --> 01:32:52,620

think about what happens if you mix up

2214
01:32:56,209 --> 01:32:55,770
the atmosphere and look at the winds and

2215
01:32:58,340 --> 01:32:56,219
so

2216
01:33:01,670 --> 01:32:58,350
and you can come up with models for the

2217
01:33:03,080 --> 01:33:01,680
dynamics that might explain that I'm not

2218
01:33:05,290 --> 01:33:03,090
going to try to do that here tonight

2219
01:33:08,180 --> 01:33:05,300
both because I'm not the right guy

2220
01:33:09,530 --> 01:33:08,190
there's some atmospheric scientists and

2221
01:33:12,020 --> 01:33:09,540
really smart people working on the

2222
01:33:13,550 --> 01:33:12,030
project working on exactly that problem

2223
01:33:15,170 --> 01:33:13,560
and if I try to explain what they're

2224
01:33:17,540 --> 01:33:15,180
doing I'm likely to get it wrong and

2225
01:33:19,400 --> 01:33:17,550
because they're not ready to publish it

2226
01:33:21,380 --> 01:33:19,410
yet so they probably wouldn't like it if

2227
01:33:22,729 --> 01:33:21,390
I said well they're speculating this and

2228
01:33:24,920 --> 01:33:22,739
that and the other and then you know

2229
01:33:26,510 --> 01:33:24,930
tomorrow they find a one where they're

2230
01:33:30,680 --> 01:33:26,520
supposed to be zero and have a different

2231
01:33:32,330 --> 01:33:30,690
answer so I'll wait till they the people

2232
01:33:35,270 --> 01:33:32,340
working on an announced that that they

2233
01:33:40,220 --> 01:33:35,280
think they understand it then somebody

2234
01:33:43,729 --> 01:33:40,230
else sent in our the Aurora on the South

2235
01:33:51,080 --> 01:33:43,739
Pole weaker because they're so spread

2236
01:33:52,910 --> 01:33:51,090
out I don't know the answer to that

2237
01:33:55,420 --> 01:33:52,920
that's not nobody knows that's just I

2238
01:34:00,050 --> 01:33:55,430

don't actually remember whether the

2239
01:34:08,270 --> 01:34:00,060
southerner or are weaker or not than the

2240
01:34:12,260 --> 01:34:08,280
northern Aurora so I can maybe send me

2241
01:34:15,800 --> 01:34:12,270
an email or send it to to JPL to our

2242
01:34:18,020 --> 01:34:15,810
outreach folks and I will try to get you

2243
01:34:20,479 --> 01:34:18,030
an answer to that whoever was watching

2244
01:34:22,640 --> 01:34:20,489
this from online I think we probably

2245
01:34:23,810 --> 01:34:22,650
know the answer to whether the northern

2246
01:34:25,610 --> 01:34:23,820
and southern roars are different

2247
01:34:29,689 --> 01:34:25,620
strength I just personally don't know

2248
01:34:32,530 --> 01:34:29,699
the answer off the top of my head all