



1
00:00:04,789 --> 00:00:02,149
you are about to hear a discussion of a

2
00:00:07,110 --> 00:00:04,799
first in the history of exploration

3
00:00:09,430 --> 00:00:07,120
the most distant human-made object

4
00:00:12,070 --> 00:00:09,440
nasa's voyager 1 spacecraft

5
00:00:14,709 --> 00:00:12,080
is an interstellar space the space

6
00:00:16,790 --> 00:00:14,719
between the stars

7
00:00:19,029 --> 00:00:16,800
this conclusion is possible because of

8
00:00:21,349 --> 00:00:19,039
data from the spacecraft's plasma waste

9
00:00:23,750 --> 00:00:21,359
science instrument built and operated by

10
00:00:25,750 --> 00:00:23,760
the university of iowa and a team led by

11
00:00:28,310 --> 00:00:25,760
don guernette

12
00:00:30,950 --> 00:00:28,320
the 36 year old probe is now sailing the

13
00:00:33,350 --> 00:00:30,960

uncharted waters of a new cosmic sea and

14

00:00:35,190 --> 00:00:33,360

it has brought us along for the journey

15

00:00:40,709 --> 00:00:35,200

now let's talk about the details of this

16

00:00:45,029 --> 00:00:42,150

ladies and gentlemen

17

00:00:46,790 --> 00:00:45,039

as you just heard today is a historic

18

00:00:50,310 --> 00:00:46,800

moment for nasa

19

00:00:52,150 --> 00:00:50,320

the voyager team and in fact humankind

20

00:00:54,150 --> 00:00:52,160

my name is dwayne brown with nasa's

21

00:00:55,350 --> 00:00:54,160

office of communications we have a lot

22

00:00:56,950 --> 00:00:55,360

to cover

23

00:00:59,029 --> 00:00:56,960

we're going to get right into it but a

24

00:01:00,950 --> 00:00:59,039

reminder that all of the information you

25

00:01:05,189 --> 00:01:00,960

will hear today and much more

26

00:01:07,429 --> 00:01:05,199

is on our website at [www dot nasa](http://www.nasa.gov)

27

00:01:09,590 --> 00:01:07,439

slash voyager

28

00:01:13,030 --> 00:01:09,600

join the conversation

29

00:01:15,830 --> 00:01:13,040

a lot will be talked about today

30

00:01:17,990 --> 00:01:15,840

twitter facebook and other social

31

00:01:18,950 --> 00:01:18,000

media venues and

32

00:01:21,030 --> 00:01:18,960

join

33

00:01:23,190 --> 00:01:21,040

the q a session

34

00:01:26,070 --> 00:01:23,200

send in your question at hashtag

35

00:01:28,149 --> 00:01:26,080

ask nasa

36

00:01:30,069 --> 00:01:28,159

before i introduce our panel

37

00:01:32,149 --> 00:01:30,079

to give opening remarks

38

00:01:33,910 --> 00:01:32,159

we should please welcome an

39

00:01:35,590 --> 00:01:33,920

astrophysicist

40

00:01:38,069 --> 00:01:35,600

five-time

41

00:01:40,310 --> 00:01:38,079

flown space shuttle astronaut

42

00:01:42,630 --> 00:01:40,320

and head or associate administrator for

43

00:01:56,469 --> 00:01:42,640

nasa's science mission directorate

44

00:01:59,749 --> 00:01:57,590

space

45

00:02:02,550 --> 00:01:59,759

the final frontier

46

00:02:04,149 --> 00:02:02,560

these are the voyages of the starship

47

00:02:06,149 --> 00:02:04,159

voyager

48

00:02:08,790 --> 00:02:06,159

its 36-year mission

49

00:02:11,350 --> 00:02:08,800

to explore strange new worlds

50

00:02:13,030 --> 00:02:11,360

to seek out anomalous cosmic rays

51
00:02:15,750 --> 00:02:13,040
and new plasmas

52
00:02:17,750 --> 00:02:15,760
to boldly go where no probe

53
00:02:19,430 --> 00:02:17,760
has gone before

54
00:02:22,390 --> 00:02:19,440
those words from star trek of course

55
00:02:24,470 --> 00:02:22,400
have inspired so many of us and i think

56
00:02:25,910 --> 00:02:24,480
are you know characteristic of of the

57
00:02:27,830 --> 00:02:25,920
excitement and the discoveries we're

58
00:02:29,670 --> 00:02:27,840
going to talk about today

59
00:02:32,229 --> 00:02:29,680
voyager like the ancient mariners is

60
00:02:34,229 --> 00:02:32,239
pushing out into new territory

61
00:02:37,110 --> 00:02:34,239
nasa's science is all about exploring

62
00:02:39,350 --> 00:02:37,120
the earth the solar system the galaxy

63
00:02:41,830 --> 00:02:39,360

and the universe itself

64

00:02:44,070 --> 00:02:41,840

someday humans will leave our cocoon in

65

00:02:45,509 --> 00:02:44,080

the solar system to explore beyond our

66

00:02:48,949 --> 00:02:45,519

home system

67

00:02:51,990 --> 00:02:48,959

voyager will have led the way

68

00:02:54,070 --> 00:02:52,000

today's excite exciting science results

69

00:02:56,550 --> 00:02:54,080

reflect a dynamic and i suspect

70

00:02:59,509 --> 00:02:56,560

continuing debate

71

00:03:02,390 --> 00:02:59,519

about the nature of our heliosphere

72

00:03:04,949 --> 00:03:02,400

this story is a story of science a story

73

00:03:07,509 --> 00:03:04,959

of exploration and a narrative about

74

00:03:09,750 --> 00:03:07,519

over 40 years of hard work

75

00:03:11,830 --> 00:03:09,760

by one of our top teams of scientists

76

00:03:13,750 --> 00:03:11,840

and engineers

77

00:03:16,470 --> 00:03:13,760

that's almost the entire history of the

78

00:03:18,390 --> 00:03:16,480

space age

79

00:03:19,910 --> 00:03:18,400

i'd personally like to salute one member

80

00:03:22,470 --> 00:03:19,920

of the team

81

00:03:24,869 --> 00:03:22,480

my former boss ed stone

82

00:03:27,589 --> 00:03:24,879

one of our country's greatest scientists

83

00:03:29,430 --> 00:03:27,599

uh and my personal hero

84

00:03:40,869 --> 00:03:29,440

and to vegeer i say

85

00:03:44,789 --> 00:03:42,470

thank you sir okay

86

00:03:47,430 --> 00:03:44,799

now to our panel

87

00:03:49,509 --> 00:03:47,440

first up you will hear

88

00:03:51,910 --> 00:03:49,519

ed stone

89

00:03:59,270 --> 00:03:51,920

voyager project scientist

90

00:04:03,589 --> 00:04:01,270

don garnett

91

00:04:05,270 --> 00:04:03,599

voyager plasma wave investigation

92

00:04:12,070 --> 00:04:05,280

principle investigator

93

00:04:15,509 --> 00:04:13,350

gary zank

94

00:04:17,749 --> 00:04:15,519

department of space sciences

95

00:04:20,789 --> 00:04:17,759

center for space plasma and

96

00:04:22,390 --> 00:04:20,799

aeronautics research or cspar

97

00:04:27,030 --> 00:04:22,400

at the university of alabama in

98

00:04:31,270 --> 00:04:28,790

and suzanne dodd

99

00:04:32,950 --> 00:04:31,280

forger project manager at nasa's jet

100

00:04:35,430 --> 00:04:32,960

propulsion laboratory

101
00:04:38,710 --> 00:04:35,440
in pasadena california and with that dr

102
00:04:41,350 --> 00:04:38,720
stone i'll turn it over to you okay

103
00:04:43,990 --> 00:04:41,360
well this is the spacecraft the first

104
00:04:46,870 --> 00:04:44,000
interstellar space we made it well we

105
00:04:49,749 --> 00:04:46,880
still had enough power to

106
00:04:52,230 --> 00:04:49,759
send back home what it was uh that we

107
00:04:54,070 --> 00:04:52,240
have now now is exploring in the this

108
00:04:58,230 --> 00:04:54,080
new region of space

109
00:05:01,270 --> 00:04:58,240
35 years uh nine 13 billion miles

110
00:05:05,110 --> 00:05:01,280
journey uh it began in 1972 when the

111
00:05:07,510 --> 00:05:05,120
project started july of 1972 uh with

112
00:05:09,830 --> 00:05:07,520
launching not two of two spacecraft in

113
00:05:13,510 --> 00:05:09,840

1977

114

00:05:17,430 --> 00:05:13,520

for jupiter saturn uranus and neptune

115

00:05:18,870 --> 00:05:17,440

that was 1989 and then in 1990 we began

116

00:05:21,510 --> 00:05:18,880

what's now called the voyager

117

00:05:23,350 --> 00:05:21,520

interstellar mission

118

00:05:25,350 --> 00:05:23,360

you might say well what is there to

119

00:05:27,670 --> 00:05:25,360

discover beyond the planets

120

00:05:29,430 --> 00:05:27,680

uh and that's what we were

121

00:05:31,830 --> 00:05:29,440

that was our job was to discover what

122

00:05:34,310 --> 00:05:31,840

was beyond the planets the sun the wind

123

00:05:36,469 --> 00:05:34,320

of the atmosphere of the sun expands

124

00:05:39,029 --> 00:05:36,479

supersonically a million miles per hour

125

00:05:40,310 --> 00:05:39,039

creating a huge bubble around all of the

126
00:05:43,110 --> 00:05:40,320

planets

127
00:05:45,590 --> 00:05:43,120

that is called the heliosphere

128
00:05:46,469 --> 00:05:45,600

and inside that bubble it's filled with

129
00:05:50,310 --> 00:05:46,479

the

130
00:05:51,909 --> 00:05:50,320

because it's ionized and that plasma

131
00:05:54,230 --> 00:05:51,919

carries out from the sun the sun's

132
00:05:57,029 --> 00:05:54,240

magnetic field and that fills this

133
00:06:00,070 --> 00:05:57,039

bubble outside the bubble the plasma

134
00:06:02,870 --> 00:06:00,080

comes from the explosion has from other

135
00:06:05,189 --> 00:06:02,880

giant stars millions of years ago

136
00:06:07,510 --> 00:06:05,199

and that plasma carries with it the

137
00:06:11,510 --> 00:06:07,520

magnetic field of the galaxy so that's

138
00:06:13,670 --> 00:06:11,520

what's inside and we are now outside

139

00:06:15,909 --> 00:06:13,680

the uh if i could have the first slide

140

00:06:18,230 --> 00:06:15,919

this is a hubble image of one of these

141

00:06:20,629 --> 00:06:18,240

astrospheres around a nearby star in the

142

00:06:22,629 --> 00:06:20,639

orion nebula and you'll notice you can't

143

00:06:24,550 --> 00:06:22,639

see the the astrosphere itself you see

144

00:06:26,629 --> 00:06:24,560

the star brightly shining

145

00:06:28,629 --> 00:06:26,639

with an orange bow shock around it but

146

00:06:31,430 --> 00:06:28,639

you can't see the object which is a

147

00:06:33,510 --> 00:06:31,440

large invisible sphere what you see is a

148

00:06:35,590 --> 00:06:33,520

shock created as the interstellar wind

149

00:06:38,070 --> 00:06:35,600

comes from the right side of that image

150

00:06:40,550 --> 00:06:38,080

and is diverted around the bubble that

151
00:06:42,390 --> 00:06:40,560
you cannot see and it glows because it's

152
00:06:44,070 --> 00:06:42,400
been excited by that

153
00:06:46,469 --> 00:06:44,080
that whole process

154
00:06:48,710 --> 00:06:46,479
we're inside of a bubble like that and

155
00:06:51,670 --> 00:06:48,720
are now out in that bright orange

156
00:06:54,150 --> 00:06:51,680
yellowish region out in front of our own

157
00:06:55,029 --> 00:06:54,160
uh bubble

158
00:06:56,950 --> 00:06:55,039
now

159
00:06:58,550 --> 00:06:56,960
the if i could have the video please

160
00:07:01,909 --> 00:06:58,560
turns out that voyager has been on its

161
00:07:04,550 --> 00:07:01,919
way for 35 years 36 years now it travels

162
00:07:07,110 --> 00:07:04,560
outward at a million miles every day

163
00:07:11,029 --> 00:07:07,120

almost a million miles a day and it was

164

00:07:13,430 --> 00:07:11,039

2004 9 billion miles from the sun before

165

00:07:15,350 --> 00:07:13,440

it ran it be had any sense of being

166

00:07:17,350 --> 00:07:15,360

close to the edge of the heliosphere

167

00:07:20,070 --> 00:07:17,360

that's when it found that the solar wind

168

00:07:22,629 --> 00:07:20,080

itself had slowed down from supersonic

169

00:07:25,990 --> 00:07:22,639

to subsonic speeds and in this picture

170

00:07:28,150 --> 00:07:26,000

you see the blue area is the heliosphere

171

00:07:30,790 --> 00:07:28,160

the darker blue is the supersonic part

172

00:07:33,029 --> 00:07:30,800

of the wind and voyager 1 crossed into

173

00:07:35,670 --> 00:07:33,039

the lair that's beyond that the dark the

174

00:07:38,550 --> 00:07:35,680

blue or somewhat darker blue area in

175

00:07:41,830 --> 00:07:38,560

december of 2004 9 billion miles from

176

00:07:43,990 --> 00:07:41,840

the sun it was another 4 billion miles

177

00:07:47,270 --> 00:07:44,000

before it reached the edge of the bubble

178

00:07:49,670 --> 00:07:47,280

and that was in august 2012. that's when

179

00:07:52,309 --> 00:07:49,680

we saw the energetic particles inside

180

00:07:53,830 --> 00:07:52,319

the bubble leak out and disappear and

181

00:07:55,909 --> 00:07:53,840

that's where we saw for the first time

182

00:07:58,070 --> 00:07:55,919

the lowest energy galactic cosmic rays

183

00:08:00,390 --> 00:07:58,080

which are in the space outside were

184

00:08:02,230 --> 00:08:00,400

suddenly could be seen

185

00:08:03,830 --> 00:08:02,240

and from that point of view it looked as

186

00:08:06,629 --> 00:08:03,840

though we had crossed

187

00:08:08,469 --> 00:08:06,639

into interstellar space but we did not

188

00:08:10,950 --> 00:08:08,479

in fact were not able to conclude that

189

00:08:13,510 --> 00:08:10,960

you might say why didn't we know in

190

00:08:15,749 --> 00:08:13,520

august last year that in fact we crossed

191

00:08:17,510 --> 00:08:15,759

in interstellar space that's because the

192

00:08:19,749 --> 00:08:17,520

boundary really is the boundary between

193

00:08:22,150 --> 00:08:19,759

these two plasmas the solar plasma of

194

00:08:24,790 --> 00:08:22,160

the wind and the interstellar plasma and

195

00:08:26,710 --> 00:08:24,800

unfortunately our plasma instrument does

196

00:08:29,909 --> 00:08:26,720

not work on voyager 1. so we could not

197

00:08:32,310 --> 00:08:29,919

directly measure these two plasmas so we

198

00:08:34,389 --> 00:08:32,320

try we used a proxy and that proxy is

199

00:08:37,190 --> 00:08:34,399

the magnetic field carried by the two

200

00:08:38,949 --> 00:08:37,200

plasmas the field carried by the sun is

201
00:08:41,430 --> 00:08:38,959
directed like this

202
00:08:43,269 --> 00:08:41,440
the field carried we thought carried by

203
00:08:45,110 --> 00:08:43,279
the interstellar

204
00:08:46,790 --> 00:08:45,120
wind was like this so we thought when we

205
00:08:48,389 --> 00:08:46,800
crossed the boundary we would see the

206
00:08:51,030 --> 00:08:48,399
field rotate

207
00:08:52,949 --> 00:08:51,040
well we crossed the boundary and

208
00:08:56,230 --> 00:08:52,959
that's what happened no change in

209
00:08:58,389 --> 00:08:56,240
direction just an increased strength of

210
00:08:59,910 --> 00:08:58,399
the field so we couldn't conclude that

211
00:09:01,910 --> 00:08:59,920
in fact we had changed plasma

212
00:09:03,269 --> 00:09:01,920
environments we couldn't directly test

213
00:09:06,230 --> 00:09:03,279

that idea

214

00:09:09,350 --> 00:09:06,240

so what do we know now uh that we

215

00:09:12,470 --> 00:09:09,360

didn't know a year ago well we were very

216

00:09:14,470 --> 00:09:12,480

fortunate that the spacecraft has on it

217

00:09:17,430 --> 00:09:14,480

besides the magnetometer which is what

218

00:09:19,590 --> 00:09:17,440

we used as a proxy we also have these

219

00:09:21,430 --> 00:09:19,600

two 10 meter antennas which are part of

220

00:09:23,509 --> 00:09:21,440

the plasma wave science instrument that

221

00:09:25,670 --> 00:09:23,519

don will talk about in a moment and that

222

00:09:27,910 --> 00:09:25,680

was very important because it gave us

223

00:09:29,590 --> 00:09:27,920

another way to measure the plasma

224

00:09:31,750 --> 00:09:29,600

assuming there were some waves in the

225

00:09:33,990 --> 00:09:31,760

plasma the last time though that

226

00:09:35,910 --> 00:09:34,000

instrument saw any waves was when we

227

00:09:37,509 --> 00:09:35,920

crossed that termination shock at the

228

00:09:39,509 --> 00:09:37,519

nine billion miles there hasn't been

229

00:09:40,630 --> 00:09:39,519

hadn't been a wave for another seven

230

00:09:43,350 --> 00:09:40,640

years

231

00:09:45,990 --> 00:09:43,360

until the sun basically had an eruption

232

00:09:47,990 --> 00:09:46,000

in march of 2012 which was fortunately

233

00:09:50,870 --> 00:09:48,000

headed in the direction of voyager

234

00:09:52,870 --> 00:09:50,880

in about 400 days it's like a tsunami it

235

00:09:56,070 --> 00:09:52,880

finally got to where voyager is it

236

00:09:58,230 --> 00:09:56,080

caused the plasma uh to react in a way

237

00:10:00,310 --> 00:09:58,240

that it could be sensed and we knew for

238

00:10:03,110 --> 00:10:00,320

the first time we were in the dense

239

00:10:05,670 --> 00:10:03,120

plasma of interstellar space

240

00:10:08,150 --> 00:10:05,680

not in the rarer plasma of the outer

241

00:10:08,949 --> 00:10:08,160

part of the solar envelope

242

00:10:11,829 --> 00:10:08,959

so

243

00:10:14,630 --> 00:10:11,839

that's a major that's a major new piece

244

00:10:16,389 --> 00:10:14,640

of data and i think it convinced most of

245

00:10:18,790 --> 00:10:16,399

us at least that we indeed are in

246

00:10:19,910 --> 00:10:18,800

interstellar space for the first time

247

00:10:22,069 --> 00:10:19,920

uh

248

00:10:24,069 --> 00:10:22,079

so that was a lucky gift from the sun

249

00:10:26,310 --> 00:10:24,079

and we hope that there will be more

250

00:10:29,190 --> 00:10:26,320

more such eruptions so that we can

251
00:10:30,710 --> 00:10:29,200
measure the plasma as we continue

252
00:10:33,030 --> 00:10:30,720
now what does it mean to reach

253
00:10:35,350 --> 00:10:33,040
interstellar space well first of all

254
00:10:37,110 --> 00:10:35,360
it's just we got there i mean this is

255
00:10:38,949 --> 00:10:37,120
something we all hoped when we started

256
00:10:41,269 --> 00:10:38,959
on this 40 years ago that this would

257
00:10:43,190 --> 00:10:41,279
happen but none of us knew how big this

258
00:10:45,190 --> 00:10:43,200
bubble was and none of us knew anything

259
00:10:46,550 --> 00:10:45,200
could last as long as the two voyager

260
00:10:48,389 --> 00:10:46,560
spacecraft so

261
00:10:50,630 --> 00:10:48,399
certainly luck is an important part of

262
00:10:52,630 --> 00:10:50,640
this but wow when we first saw that data

263
00:10:54,790 --> 00:10:52,640

a year ago it was really quite stunning

264

00:10:55,670 --> 00:10:54,800

after having been on the way for so many

265

00:10:57,910 --> 00:10:55,680

years

266

00:11:00,230 --> 00:10:57,920

uh this remarkable journey

267

00:11:02,790 --> 00:11:00,240

is clearly a tribute to the many

268

00:11:04,310 --> 00:11:02,800

individuals responsible for the success

269

00:11:05,910 --> 00:11:04,320

of the voyager mission over the last

270

00:11:08,630 --> 00:11:05,920

four decades

271

00:11:11,030 --> 00:11:08,640

in leaving the heliosphere and setting

272

00:11:15,350 --> 00:11:11,040

sail on the cosmic seas between the

273

00:11:18,310 --> 00:11:15,360

stars voyager has joined the other uh

274

00:11:21,190 --> 00:11:18,320

historic journeys of exploration such as

275

00:11:23,750 --> 00:11:21,200

the first circumnavigation of the earth

276

00:11:26,790 --> 00:11:23,760

and the first footprint on the moon

277

00:11:28,949 --> 00:11:26,800

this historic step is even more exciting

278

00:11:32,150 --> 00:11:28,959

because it marks the beginning

279

00:11:34,870 --> 00:11:32,160

of a new era of exploration for villager

280

00:11:36,949 --> 00:11:34,880

the exploration of this of the space

281

00:11:38,069 --> 00:11:36,959

between the stars so i'll turn it over

282

00:11:39,750 --> 00:11:38,079

to don

283

00:11:41,590 --> 00:11:39,760

thanks a lot ed for the introduction and

284

00:11:42,630 --> 00:11:41,600

for commenting on the plasma wave

285

00:11:44,710 --> 00:11:42,640

instrument

286

00:11:47,509 --> 00:11:44,720

well as ed said

287

00:11:49,590 --> 00:11:47,519

the real issue here is plasmas

288

00:11:51,430 --> 00:11:49,600

which kind of plasma are we in are we in

289

00:11:52,629 --> 00:11:51,440

the solar plasma or the interstellar

290

00:11:54,790 --> 00:11:52,639

plasma

291

00:11:56,790 --> 00:11:54,800

now it's just an unfortunate thing that

292

00:11:58,790 --> 00:11:56,800

the instrument that was designed to

293

00:12:03,190 --> 00:11:58,800

measure plasmas

294

00:12:05,350 --> 00:12:03,200

failed a long time ago about 1980.

295

00:12:07,910 --> 00:12:05,360

now the instrument that i'm responsible

296

00:12:09,750 --> 00:12:07,920

for the plasma wave instrument

297

00:12:12,069 --> 00:12:09,760

it's designed to measure waves

298

00:12:14,150 --> 00:12:12,079

propagating in this ionized media out

299

00:12:15,750 --> 00:12:14,160

there we call plasma

300

00:12:17,430 --> 00:12:15,760

it's kind of an exotic subject but

301

00:12:19,350 --> 00:12:17,440

there's a lot of different types of

302

00:12:21,430 --> 00:12:19,360

waves propagates some they're just like

303

00:12:23,190 --> 00:12:21,440

sound waves like i'm talking with here

304

00:12:24,949 --> 00:12:23,200

they're called ion sound waves they

305

00:12:27,269 --> 00:12:24,959

propagate

306

00:12:29,509 --> 00:12:27,279

sometimes great distances

307

00:12:32,629 --> 00:12:29,519

they're also radio waves

308

00:12:34,389 --> 00:12:32,639

now our instrument consists of two long

309

00:12:36,069 --> 00:12:34,399

electric antennas if you bring up the

310

00:12:37,750 --> 00:12:36,079

picture of voyager

311

00:12:38,550 --> 00:12:37,760

you can see them there they're 10 meters

312

00:12:40,629 --> 00:12:38,560

long

313

00:12:42,389 --> 00:12:40,639

and we essentially have a radio receiver

314

00:12:44,150 --> 00:12:42,399

at the base of those antennas i might

315

00:12:45,190 --> 00:12:44,160

comment those antennas are kind of like

316

00:12:46,790 --> 00:12:45,200

the

317

00:12:48,870 --> 00:12:46,800

v-shaped antennas you used to have

318

00:12:50,470 --> 00:12:48,880

sitting on top of your tv you know the

319

00:12:52,870 --> 00:12:50,480

rabbit ears

320

00:12:55,190 --> 00:12:52,880

well we can detect radio emissions

321

00:12:57,350 --> 00:12:55,200

jupiter saturn and these outer planets

322

00:12:59,430 --> 00:12:57,360

are very intense radio emitters and

323

00:13:00,710 --> 00:12:59,440

we've done a lot of research on radio

324

00:13:03,590 --> 00:13:00,720

emissions

325

00:13:05,750 --> 00:13:03,600

but as i said you can also detect waves

326

00:13:07,829 --> 00:13:05,760

propagating in the plasma now there's

327

00:13:10,069 --> 00:13:07,839

one type of wave that's particularly

328

00:13:11,750 --> 00:13:10,079

important for us it's called an electron

329

00:13:13,750 --> 00:13:11,760

plasma oscillation

330

00:13:15,509 --> 00:13:13,760

you'll have an exam afterwards on quizzzy

331

00:13:18,310 --> 00:13:15,519

on the properties of this

332

00:13:21,430 --> 00:13:18,320

if you displace the electrons from the

333

00:13:23,269 --> 00:13:21,440

ions and release them there's attractive

334

00:13:24,790 --> 00:13:23,279

force and the electrons will proceed to

335

00:13:26,550 --> 00:13:24,800

oscillate back and forth at a

336

00:13:29,509 --> 00:13:26,560

characteristic frequency that we call

337

00:13:30,790 --> 00:13:29,519

the electron plasma frequency

338

00:13:33,829 --> 00:13:30,800

it turns out

339

00:13:37,190 --> 00:13:33,839

this oscillation frequency is

340

00:13:39,750 --> 00:13:37,200

directly related to the plasma density

341

00:13:41,509 --> 00:13:39,760

the number of particles say per per

342

00:13:43,670 --> 00:13:41,519

cubic meter

343

00:13:46,150 --> 00:13:43,680

and that's a very important

344

00:13:48,949 --> 00:13:46,160

quantity to try to distinguish between

345

00:13:51,189 --> 00:13:48,959

the interstellar plasma and the solar

346

00:13:53,350 --> 00:13:51,199

plasma because it turns out for reasons

347

00:13:55,269 --> 00:13:53,360

i'll try to explain shortly

348

00:13:57,670 --> 00:13:55,279

the interstellar plasma is actually

349

00:14:00,470 --> 00:13:57,680

considerably has considerably higher

350

00:14:03,990 --> 00:14:00,480

density than the solar plasma

351
00:14:05,670 --> 00:14:04,000
so we can detect uh these waves uh when

352
00:14:08,870 --> 00:14:05,680
the oscillation occurs kind of like a

353
00:14:11,670 --> 00:14:08,880
vibration uh uh in the uh

354
00:14:13,110 --> 00:14:11,680
plasma but unfortunately we don't do it

355
00:14:16,069 --> 00:14:13,120
all the time

356
00:14:18,150 --> 00:14:16,079
and i'll get into why for example when

357
00:14:19,829 --> 00:14:18,160
when we saw the cosmic ray changes

358
00:14:21,509 --> 00:14:19,839
unfortunately we didn't have any plasma

359
00:14:22,710 --> 00:14:21,519
oscillations so we couldn't tell you the

360
00:14:24,710 --> 00:14:22,720
density

361
00:14:27,189 --> 00:14:24,720
now okay so when can we measure the

362
00:14:30,629 --> 00:14:27,199
plasma oscillations well it's got to do

363
00:14:32,230 --> 00:14:30,639

with the presence of an electron beam uh

364

00:14:33,990 --> 00:14:32,240

you know it's like a wind instrument if

365

00:14:36,790 --> 00:14:34,000

you got air blowing in a wind instrument

366

00:14:37,910 --> 00:14:36,800

you sometimes get a distinct pitch or

367

00:14:39,189 --> 00:14:37,920

sound

368

00:14:41,350 --> 00:14:39,199

sort of like that

369

00:14:43,750 --> 00:14:41,360

okay where do we get electron beams we

370

00:14:46,470 --> 00:14:43,760

get those from solar events

371

00:14:48,550 --> 00:14:46,480

big explosions on the sun that eject

372

00:14:50,710 --> 00:14:48,560

plasma out from the sun that's all

373

00:14:53,189 --> 00:14:50,720

called coronal mass ejections and you

374

00:14:55,910 --> 00:14:53,199

can run the soho image there it'll show

375

00:14:57,750 --> 00:14:55,920

some examples soho image i hope it's

376

00:15:00,870 --> 00:14:57,760

running

377

00:15:03,350 --> 00:15:00,880

anyway these ejections come out at very

378

00:15:04,710 --> 00:15:03,360

high velocities million over a million

379

00:15:08,069 --> 00:15:04,720

miles an hour

380

00:15:09,590 --> 00:15:08,079

and sometimes they're very dense a blast

381

00:15:12,230 --> 00:15:09,600

of plasma coming out from the sun

382

00:15:15,670 --> 00:15:12,240

propagates great distances takes almost

383

00:15:18,389 --> 00:15:15,680

a year to get out to voyager distances

384

00:15:20,230 --> 00:15:18,399

ahead of those blast waves electrons are

385

00:15:22,389 --> 00:15:20,240

accelerated at the shock that's in front

386

00:15:24,069 --> 00:15:22,399

of them and they stimulate our plasma

387

00:15:26,870 --> 00:15:24,079

oscillations

388

00:15:27,910 --> 00:15:26,880

now it turned out after the cosmic ray

389

00:15:30,310 --> 00:15:27,920

change

390

00:15:33,829 --> 00:15:30,320

about a month and a half later in

391

00:15:36,150 --> 00:15:33,839

october november 2012 we detected

392

00:15:38,790 --> 00:15:36,160

plasma oscillations

393

00:15:40,710 --> 00:15:38,800

and it was created by a solar event that

394

00:15:42,550 --> 00:15:40,720

frankly we're still trying to study

395

00:15:44,470 --> 00:15:42,560

exactly what event it was it's sort of

396

00:15:45,990 --> 00:15:44,480

hard over such great distances to make

397

00:15:48,069 --> 00:15:46,000

those connections

398

00:15:50,629 --> 00:15:48,079

then there was another event in

399

00:15:52,230 --> 00:15:50,639

this year in april may that was even

400

00:15:54,790 --> 00:15:52,240

stronger

401
00:15:56,949 --> 00:15:54,800
now i'm going to show you shortly a

402
00:15:58,150 --> 00:15:56,959
spectrogram a plot of frequency versus

403
00:15:59,189 --> 00:15:58,160
time

404
00:16:01,030 --> 00:15:59,199
and

405
00:16:02,870 --> 00:16:01,040
on that spectrogram

406
00:16:06,069 --> 00:16:02,880
these oscillations that i'm talking

407
00:16:08,310 --> 00:16:06,079
about occur at audio frequencies

408
00:16:09,829 --> 00:16:08,320
so with our receiver we can actually

409
00:16:11,350 --> 00:16:09,839
transmit them back to the ground

410
00:16:14,150 --> 00:16:11,360
actually what happens it gets stored in

411
00:16:15,910 --> 00:16:14,160
a spacecraft tape recorder which we play

412
00:16:17,829 --> 00:16:15,920
back every six months so there's some

413
00:16:18,870 --> 00:16:17,839

big time delays involved here that's one

414

00:16:20,790 --> 00:16:18,880
of the reasons we're a little late

415

00:16:23,110 --> 00:16:20,800
reporting this

416

00:16:24,870 --> 00:16:23,120
but you can play it back and then uh you

417

00:16:27,350 --> 00:16:24,880
can actually listen to it

418

00:16:29,829 --> 00:16:27,360
uh so what i'm going to do is uh start

419

00:16:32,389 --> 00:16:29,839
this recording not yet however

420

00:16:34,150 --> 00:16:32,399
and you'll see a cursor moving it i have

421

00:16:36,150 --> 00:16:34,160
a seven month interval that i show there

422

00:16:37,430 --> 00:16:36,160
that we compressed fortunately to 15

423

00:16:39,590 --> 00:16:37,440
seconds we aren't going to sit here and

424

00:16:41,350 --> 00:16:39,600
listen for seven months to these things

425

00:16:44,629 --> 00:16:41,360
but what you'll hear you'll hear the

426

00:16:46,870 --> 00:16:44,639

first october november uh

427

00:16:48,230 --> 00:16:46,880

2012 event then there'll be a little bit

428

00:16:51,829 --> 00:16:48,240

of a gap where you don't hear anything

429

00:16:54,310 --> 00:16:51,839

then you'll hear the uh the april may

430

00:16:57,350 --> 00:16:54,320

2013 event

431

00:17:00,230 --> 00:16:57,360

so when you hear this recording

432

00:17:02,310 --> 00:17:00,240

please recognize it's a historic event

433

00:17:05,350 --> 00:17:02,320

it's the first time that we've ever made

434

00:17:06,309 --> 00:17:05,360

a recording of sounds in interstellar

435

00:17:23,270 --> 00:17:06,319

space

436

00:17:27,669 --> 00:17:25,189

sounds as i tried to explain from the

437

00:17:29,350 --> 00:17:27,679

frequency we can compute very accurately

438

00:17:31,190 --> 00:17:29,360

the plasma density

439

00:17:33,430 --> 00:17:31,200

and it turned out to be about a hundred

440

00:17:35,830 --> 00:17:33,440

thousand per cubic cent

441

00:17:38,630 --> 00:17:35,840

per cubic meter just almost exactly what

442

00:17:40,870 --> 00:17:38,640

we expected the interstellar

443

00:17:43,350 --> 00:17:40,880

plasma in fact when we saw the first

444

00:17:45,750 --> 00:17:43,360

event i just myself my colleague bill

445

00:17:46,950 --> 00:17:45,760

kurth we said we're in the interstellar

446

00:17:48,549 --> 00:17:46,960

plasma

447

00:17:50,710 --> 00:17:48,559

now you'll notice another thing in that

448

00:17:52,310 --> 00:17:50,720

recording uh the frequency was

449

00:17:54,310 --> 00:17:52,320

increasing uh

450

00:17:56,630 --> 00:17:54,320

let's play it again i put a dashed line

451
00:17:59,430 --> 00:17:56,640
on this on the spectrogram so you can

452
00:18:14,950 --> 00:17:59,440
kind of get an idea how it's increasing

453
00:18:19,590 --> 00:18:17,029
so this is evidence that we're propaga

454
00:18:22,150 --> 00:18:19,600
where the spacecraft is moving into what

455
00:18:24,230 --> 00:18:22,160
i term a density ramp a slowly

456
00:18:26,470 --> 00:18:24,240
increasing plasma density

457
00:18:29,510 --> 00:18:26,480
and my colleague over here gary zank

458
00:18:31,350 --> 00:18:29,520
will shortly but not right now

459
00:18:34,549 --> 00:18:31,360
explain that ramp

460
00:18:37,270 --> 00:18:34,559
i have to tell you that we made radio

461
00:18:39,909 --> 00:18:37,280
the detections of the heliopause

462
00:18:43,669 --> 00:18:39,919
20 years ago in 1993

463
00:18:45,750 --> 00:18:43,679

and i detected that same ramp

464

00:18:47,830 --> 00:18:45,760

as a shock wave propagated into the

465

00:18:50,070 --> 00:18:47,840

interstellar medium and the and the

466

00:18:52,390 --> 00:18:50,080

radio frequency which is at the plasma

467

00:18:55,029 --> 00:18:52,400

the same frequency gradually rose and

468

00:18:57,190 --> 00:18:55,039

those two observations seem to match

469

00:18:59,190 --> 00:18:57,200

almost perfectly

470

00:19:01,430 --> 00:18:59,200

well let me go in a little more into

471

00:19:02,950 --> 00:19:01,440

what all this means

472

00:19:04,710 --> 00:19:02,960

if you'll show the next

473

00:19:07,270 --> 00:19:04,720

illustration this is actually one of

474

00:19:10,470 --> 00:19:07,280

gary's thanks illustrations

475

00:19:13,590 --> 00:19:10,480

and it shows there the

476

00:19:16,870 --> 00:19:13,600

the sort of bullet-shaped heliopause

477

00:19:18,950 --> 00:19:16,880

and inside the heliopause is that hot

478

00:19:20,230 --> 00:19:18,960

plasma from solar wind that flows out

479

00:19:22,230 --> 00:19:20,240

from the sun

480

00:19:24,470 --> 00:19:22,240

and the very hottest part is out there

481

00:19:27,029 --> 00:19:24,480

where it shows a red

482

00:19:29,430 --> 00:19:27,039

in that region the temperature

483

00:19:31,669 --> 00:19:29,440

is on the order of a million degrees or

484

00:19:32,950 --> 00:19:31,679

even several million degrees extremely

485

00:19:34,390 --> 00:19:32,960

hot

486

00:19:36,470 --> 00:19:34,400

and then

487

00:19:39,110 --> 00:19:36,480

the heliopause occurs then the blue

488

00:19:41,510 --> 00:19:39,120

region is the interstellar plasma

489

00:19:43,029 --> 00:19:41,520

and in the interstellar plasma

490

00:19:45,190 --> 00:19:43,039

we have various reasons to think the

491

00:19:47,190 --> 00:19:45,200

temperature is more modest

492

00:19:49,909 --> 00:19:47,200

still height my terrestrial standards

493

00:19:51,110 --> 00:19:49,919

but about 6 000 degrees so you have this

494

00:19:52,549 --> 00:19:51,120

tremendous

495

00:19:54,230 --> 00:19:52,559

temperature difference across the

496

00:19:56,390 --> 00:19:54,240

heliopause

497

00:19:57,750 --> 00:19:56,400

and to balance the pressure at the

498

00:20:00,549 --> 00:19:57,760

heliopause you have to have a

499

00:20:01,990 --> 00:20:00,559

corresponding increase in the plasma

500

00:20:06,230 --> 00:20:02,000

density

501
00:20:08,630 --> 00:20:06,240
into the interstellar being

502
00:20:10,310 --> 00:20:08,640
interstellar plasma that may seem

503
00:20:11,510 --> 00:20:10,320
counter-intuitive you might think the

504
00:20:13,510 --> 00:20:11,520
interstellar

505
00:20:15,110 --> 00:20:13,520
you know plasma is it's like a vacuum

506
00:20:17,350 --> 00:20:15,120
but it's not the density actually goes

507
00:20:20,310 --> 00:20:17,360
up substantially

508
00:20:21,750 --> 00:20:20,320
and as i described we just measured the

509
00:20:23,909 --> 00:20:21,760
density on the

510
00:20:27,190 --> 00:20:23,919
on the interstellar side if you go to

511
00:20:29,430 --> 00:20:27,200
the next slide i show a plot

512
00:20:31,669 --> 00:20:29,440
of the plasma density as you come out

513
00:20:34,710 --> 00:20:31,679

from the sun on the left

514

00:20:35,909 --> 00:20:34,720

and the red is a very hot gas from the

515

00:20:38,070 --> 00:20:35,919

sun

516

00:20:40,710 --> 00:20:38,080

and on the right

517

00:20:42,950 --> 00:20:40,720

is the interstellar plasma which i

518

00:20:44,710 --> 00:20:42,960

colored blue because it's cool

519

00:20:46,310 --> 00:20:44,720

and you'll notice

520

00:20:47,510 --> 00:20:46,320

right at the heliopause there's that

521

00:20:48,870 --> 00:20:47,520

very large

522

00:20:50,630 --> 00:20:48,880

jump which has got to do with the

523

00:20:52,789 --> 00:20:50,640

temperature differences now we've

524

00:20:55,350 --> 00:20:52,799

actually measured the plasma density on

525

00:20:58,149 --> 00:20:55,360

the solar site at the termination shock

526

00:21:00,310 --> 00:20:58,159

like ed said nine years ago

527

00:21:02,789 --> 00:21:00,320

we detected plasma oscillations at the

528

00:21:05,110 --> 00:21:02,799

shock we often detect a lot of waves at

529

00:21:07,510 --> 00:21:05,120

the shock wave and the frequency there

530

00:21:09,270 --> 00:21:07,520

was 300 hertz

531

00:21:10,630 --> 00:21:09,280

much lower than the frequency we were

532

00:21:13,350 --> 00:21:10,640

talking about now

533

00:21:15,430 --> 00:21:13,360

and i forgot to tell you the density

534

00:21:16,789 --> 00:21:15,440

goes is the frequency squared that's

535

00:21:17,590 --> 00:21:16,799

going to be part of the quiz i'll give

536

00:21:19,190 --> 00:21:17,600

you

537

00:21:21,510 --> 00:21:19,200

and uh

538

00:21:23,990 --> 00:21:21,520

so since the frequency went up a factor

539

00:21:26,070 --> 00:21:24,000

of 10 that meant the density went up a

540

00:21:28,149 --> 00:21:26,080

factor of 100. so there's this huge

541

00:21:30,789 --> 00:21:28,159

density jump across the

542

00:21:32,230 --> 00:21:30,799

heliopause in fact we by extrapolating

543

00:21:33,830 --> 00:21:32,240

our measurements we

544

00:21:36,070 --> 00:21:33,840

we make an argument in our paper that

545

00:21:38,549 --> 00:21:36,080

that density jump actually occurred on

546

00:21:40,470 --> 00:21:38,559

or around august 25th where the cosmic

547

00:21:42,230 --> 00:21:40,480

rays occur so that's probably where we

548

00:21:44,789 --> 00:21:42,240

entered into what i would call

549

00:21:48,149 --> 00:21:44,799

interstellar space anyway a very

550

00:21:49,909 --> 00:21:48,159

exciting time for me i've i've worked

551
00:21:52,230 --> 00:21:49,919
well i've been working in space research

552
00:21:54,630 --> 00:21:52,240
for 55 years i started working with jim

553
00:21:55,990 --> 00:21:54,640
van allen incidentally jim van allen was

554
00:21:59,190 --> 00:21:56,000
very interested in reaching the

555
00:22:01,350 --> 00:21:59,200
heliopause with pioneers 10 and 11 but

556
00:22:03,590 --> 00:22:01,360
unfortunately the spacecraft

557
00:22:05,830 --> 00:22:03,600
stopped operating first and he died

558
00:22:07,669 --> 00:22:05,840
several years ago i think he'd be very

559
00:22:09,590 --> 00:22:07,679
proud to

560
00:22:10,830 --> 00:22:09,600
to hear this event and maybe he's

561
00:22:13,430 --> 00:22:10,840
actually

562
00:22:16,310 --> 00:22:13,440
listening i'll introduce gary zank my

563
00:22:17,750 --> 00:22:16,320

colleague here well thanks don um

564

00:22:19,590 --> 00:22:17,760

that was just

565

00:22:21,830 --> 00:22:19,600

the news when don first called me this

566

00:22:23,430 --> 00:22:21,840

was a little before the paper was quite

567

00:22:25,270 --> 00:22:23,440

extraordinary he

568

00:22:26,789 --> 00:22:25,280

i think called me to sound me out a

569

00:22:30,470 --> 00:22:26,799

little bit about some of some of the

570

00:22:33,110 --> 00:22:30,480

models that we were developing and and

571

00:22:35,430 --> 00:22:33,120

he told me that the plasma frequency had

572

00:22:37,750 --> 00:22:35,440

suggested that the

573

00:22:39,350 --> 00:22:37,760

number density the plasma density that

574

00:22:42,070 --> 00:22:39,360

they were measuring was on the order of

575

00:22:44,149 --> 00:22:42,080

of about .08 particles per cubic

576

00:22:47,270 --> 00:22:44,159

centimeter and i took i think it took us

577

00:22:48,710 --> 00:22:47,280

both what all of 10 seconds 15 seconds

578

00:22:50,950 --> 00:22:48,720

to conclude that we had to be in the

579

00:22:52,950 --> 00:22:50,960

interstellar medium and so why did we

580

00:22:55,430 --> 00:22:52,960

conclude that i think if we pull up the

581

00:22:57,430 --> 00:22:55,440

first figure there's a simulation these

582

00:22:59,190 --> 00:22:57,440

are the this looks quite simple but it

583

00:23:01,830 --> 00:22:59,200

comes from an extraordinarily complex

584

00:23:04,310 --> 00:23:01,840

set of simulations um that that we run

585

00:23:06,549 --> 00:23:04,320

on on a lot of the sort of top-end

586

00:23:08,630 --> 00:23:06,559

supercomputers around the country

587

00:23:11,350 --> 00:23:08,640

but what you can see in that blue side

588

00:23:13,350 --> 00:23:11,360

is is the interstellar medium region and

589

00:23:16,230 --> 00:23:13,360

you'll notice on the left side is is

590

00:23:18,390 --> 00:23:16,240

white and the white in fact is is the

591

00:23:19,830 --> 00:23:18,400

solar material the material that came

592

00:23:21,909 --> 00:23:19,840

from the sun

593

00:23:23,830 --> 00:23:21,919

and these computer simulations

594

00:23:25,909 --> 00:23:23,840

illustrate very very clearly that there

595

00:23:29,190 --> 00:23:25,919

should be an enormous jump in going from

596

00:23:32,149 --> 00:23:29,200

the solar side to the interstellar side

597

00:23:34,310 --> 00:23:32,159

in the density of the of the plasma

598

00:23:36,470 --> 00:23:34,320

that plasma jump in fact is on the order

599

00:23:39,350 --> 00:23:36,480

of a hundred times

600

00:23:41,350 --> 00:23:39,360

now you might ask why in fact was the

601
00:23:43,269 --> 00:23:41,360
instrument not observing something that

602
00:23:44,630 --> 00:23:43,279
could have been in the solar in the

603
00:23:46,310 --> 00:23:44,640
solar

604
00:23:47,350 --> 00:23:46,320
medium instead of the interstellar

605
00:23:48,950 --> 00:23:47,360
medium

606
00:23:50,950 --> 00:23:48,960
for example these very strong

607
00:23:52,230 --> 00:23:50,960
tsunami-like shocks that that ed

608
00:23:54,950 --> 00:23:52,240
referred to

609
00:23:56,710 --> 00:23:54,960
well we've examined that and and we know

610
00:23:58,950 --> 00:23:56,720
from the simulations and from the

611
00:24:00,230 --> 00:23:58,960
expectations of the underlying theory

612
00:24:02,390 --> 00:24:00,240
that in fact

613
00:24:05,190 --> 00:24:02,400

such huge enhancements of the number

614

00:24:07,990 --> 00:24:05,200

density are impossible to get within the

615

00:24:09,990 --> 00:24:08,000

within the um within the solar medium it

616

00:24:11,830 --> 00:24:10,000

has to be that we crossed over the

617

00:24:13,430 --> 00:24:11,840

interstellar medium the other thing that

618

00:24:15,269 --> 00:24:13,440

you'll notice interestingly about that

619

00:24:17,830 --> 00:24:15,279

figure is that in fact although it looks

620

00:24:20,470 --> 00:24:17,840

very steep that line that jumps from the

621

00:24:21,909 --> 00:24:20,480

in solar side to the interstellar side

622

00:24:24,390 --> 00:24:21,919

is in fact

623

00:24:26,390 --> 00:24:24,400

somewhat gradual there is a ramp there

624

00:24:29,669 --> 00:24:26,400

and that ramp gradually increases and so

625

00:24:31,669 --> 00:24:29,679

that again is is very consistent with um

626

00:24:33,190 --> 00:24:31,679

with the kind of observations that that

627

00:24:34,470 --> 00:24:33,200

don is reporting

628

00:24:37,510 --> 00:24:34,480

so that transition is called the

629

00:24:40,149 --> 00:24:37,520

heliopauses as don indicated

630

00:24:42,149 --> 00:24:40,159

and and it has this hundred-fold um

631

00:24:44,310 --> 00:24:42,159

increase and so consequently because

632

00:24:46,070 --> 00:24:44,320

there's no other possible explanation i

633

00:24:47,669 --> 00:24:46,080

think we're forced and we're obliged to

634

00:24:49,350 --> 00:24:47,679

conclude that we are in fact in the

635

00:24:50,470 --> 00:24:49,360

interstellar medium

636

00:24:52,230 --> 00:24:50,480

um

637

00:24:54,310 --> 00:24:52,240

this is is truly a remarkable

638

00:24:56,630 --> 00:24:54,320

achievement i believe it's very hard for

639

00:24:57,269 --> 00:24:56,640

us as i said to comprehend that um you

640

00:25:01,350 --> 00:24:57,279

know

641

00:25:03,750 --> 00:25:01,360

the space age started 55 years ago and

642

00:25:06,149 --> 00:25:03,760

in that period we've actually exited the

643

00:25:08,310 --> 00:25:06,159

solar system we we've exited the

644

00:25:10,230 --> 00:25:08,320

material that's created by the sun and

645

00:25:11,669 --> 00:25:10,240

we're in a truly alien environment the

646

00:25:13,990 --> 00:25:11,679

material in which

647

00:25:16,230 --> 00:25:14,000

voyager finds itself is not created by

648

00:25:18,789 --> 00:25:16,240

the sun it's created in fact by by our

649

00:25:21,029 --> 00:25:18,799

neighboring stars um supernova remnants

650

00:25:24,390 --> 00:25:21,039

and so forth and so voyager

651
00:25:26,149 --> 00:25:24,400
in some very real sense is is material

652
00:25:30,070 --> 00:25:26,159
that's not from the medium in which it

653
00:25:32,630 --> 00:25:30,080
finds itself so we've truly crossed over

654
00:25:35,350 --> 00:25:32,640
nonetheless voyager has and continues

655
00:25:37,590 --> 00:25:35,360
and i expect it will continue to do so

656
00:25:38,549 --> 00:25:37,600
has a remarkable capacity to surprise

657
00:25:40,549 --> 00:25:38,559
and so

658
00:25:42,710 --> 00:25:40,559
even though in some sense the

659
00:25:45,510 --> 00:25:42,720
observations that voyager has presented

660
00:25:47,590 --> 00:25:45,520
us with in terms of the density and also

661
00:25:49,990 --> 00:25:47,600
in terms of the anomalous and galactic

662
00:25:52,390 --> 00:25:50,000
cosmic rays those are all consistent

663
00:25:54,390 --> 00:25:52,400

with our expectations theoretically it

664

00:25:56,390 --> 00:25:54,400

turns out that the magnetic field as ed

665

00:25:58,549 --> 00:25:56,400

alluded to is is still something that

666

00:26:01,350 --> 00:25:58,559

puzzles us considerably

667

00:26:03,350 --> 00:26:01,360

and if we go to the next slide

668

00:26:05,430 --> 00:26:03,360

our expectations were that the

669

00:26:07,190 --> 00:26:05,440

interstellar medium had a had a magnetic

670

00:26:10,230 --> 00:26:07,200

field that was oriented in a certain

671

00:26:12,470 --> 00:26:10,240

direction and the interplanetary

672

00:26:15,110 --> 00:26:12,480

magnetic field which is effectively like

673

00:26:17,510 --> 00:26:15,120

a big archimedean spiral

674

00:26:19,830 --> 00:26:17,520

meant that the orientation between the

675

00:26:21,830 --> 00:26:19,840

magnetic field on the solar side and the

676
00:26:23,830 --> 00:26:21,840
orientation of the magnetic field on the

677
00:26:25,830 --> 00:26:23,840
interstellar side would be somewhat

678
00:26:28,310 --> 00:26:25,840
significantly different possibly by as

679
00:26:30,230 --> 00:26:28,320
much as about 30 degrees

680
00:26:32,390 --> 00:26:30,240
and there would most likely be an

681
00:26:34,149 --> 00:26:32,400
increase or a significant change in the

682
00:26:36,149 --> 00:26:34,159
magnetic field strength well what

683
00:26:37,750 --> 00:26:36,159
voyager saw is illustrated on the right

684
00:26:39,110 --> 00:26:37,760
of that figure you can see the little

685
00:26:40,470 --> 00:26:39,120
red and the little green and the little

686
00:26:43,590 --> 00:26:40,480
sort of um

687
00:26:45,830 --> 00:26:43,600
latter colored green curve and in fact

688
00:26:47,190 --> 00:26:45,840

there was almost no change very little

689

00:26:49,830 --> 00:26:47,200

change at all

690

00:26:51,430 --> 00:26:49,840

and so this is is is a real puzzle as to

691

00:26:54,149 --> 00:26:51,440

what is happening what is the physics

692

00:26:57,750 --> 00:26:54,159

that underlies this this absence of of

693

00:26:59,590 --> 00:26:57,760

of sudden change in the magnetic field

694

00:27:01,510 --> 00:26:59,600

and the reason why this is so puzzling

695

00:27:03,350 --> 00:27:01,520

is if we go to the next slide there's a

696

00:27:04,789 --> 00:27:03,360

series of three

697

00:27:07,110 --> 00:27:04,799

figures

698

00:27:09,590 --> 00:27:07,120

these the top figure is observations

699

00:27:11,830 --> 00:27:09,600

that were obtained by what's by the ibex

700

00:27:14,950 --> 00:27:11,840

spacecraft the interstellar boundary

701
00:27:17,669 --> 00:27:14,960
explorer and what it shows is in a sense

702
00:27:19,590 --> 00:27:17,679
messengers and very energetic particles

703
00:27:21,350 --> 00:27:19,600
that are created neutral particles that

704
00:27:23,909 --> 00:27:21,360
are created in the boundaries of this

705
00:27:26,070 --> 00:27:23,919
region that come to us and are measured

706
00:27:26,950 --> 00:27:26,080
by the spacecraft at one astronomical

707
00:27:29,430 --> 00:27:26,960
unit

708
00:27:31,350 --> 00:27:29,440
and the surprise in these observations

709
00:27:33,510 --> 00:27:31,360
was there was this so called ribbon that

710
00:27:34,789 --> 00:27:33,520
region of green enhancement that you see

711
00:27:36,710 --> 00:27:34,799
in the figure

712
00:27:38,470 --> 00:27:36,720
that was completely unexpected we

713
00:27:40,870 --> 00:27:38,480

managed to explain it or at least we

714

00:27:42,070 --> 00:27:40,880

thought we had managed to explain it

715

00:27:47,830 --> 00:27:42,080

by

716

00:27:49,430 --> 00:27:47,840

relied very strongly on a certain

717

00:27:51,430 --> 00:27:49,440

orientation and strength of the

718

00:27:53,990 --> 00:27:51,440

interstellar magnetic field

719

00:27:55,909 --> 00:27:54,000

and when we use this orientation and we

720

00:27:57,830 --> 00:27:55,919

ran these big computer simulations and

721

00:27:59,669 --> 00:27:57,840

we incorporated this additional physics

722

00:28:01,990 --> 00:27:59,679

what we obtained was that figure on the

723

00:28:03,830 --> 00:28:02,000

lower left and you can see that in fact

724

00:28:05,750 --> 00:28:03,840

theoretically it does an excellent job

725

00:28:08,389 --> 00:28:05,760

of agreeing with the voyager with the

726

00:28:09,909 --> 00:28:08,399

ibex observed ribbon

727

00:28:11,830 --> 00:28:09,919

unfortunately if you change that

728

00:28:14,389 --> 00:28:11,840

magnetic field around and change its

729

00:28:15,909 --> 00:28:14,399

orientation and even its strength you

730

00:28:18,470 --> 00:28:15,919

end up with something that looks more

731

00:28:20,149 --> 00:28:18,480

like the bottom panel on the right which

732

00:28:21,830 --> 00:28:20,159

is a ribbon that doesn't agree with the

733

00:28:24,070 --> 00:28:21,840

observations at all

734

00:28:25,909 --> 00:28:24,080

so we have now two constraints one is

735

00:28:28,549 --> 00:28:25,919

we're in the interstellar medium voyager

736

00:28:30,630 --> 00:28:28,559

has told us that the interstellar plasma

737

00:28:32,870 --> 00:28:30,640

density is significantly high and

738

00:28:34,230 --> 00:28:32,880

there's almost no other conclusion that

739

00:28:37,110 --> 00:28:34,240

we can come to

740

00:28:38,710 --> 00:28:37,120

and on the other hand we have

741

00:28:41,430 --> 00:28:38,720

a magnetic field

742

00:28:44,230 --> 00:28:41,440

that can explain ibex observations and

743

00:28:45,830 --> 00:28:44,240

we have no theory whatsoever to to

744

00:28:47,510 --> 00:28:45,840

bridge this gap

745

00:28:49,510 --> 00:28:47,520

so we're in the fortunate position i'm

746

00:28:50,950 --> 00:28:49,520

not sure if ed and don agree but we're

747

00:28:52,630 --> 00:28:50,960

in the fortunate position of having

748

00:28:54,950 --> 00:28:52,640

another good few years of trying to

749

00:28:56,630 --> 00:28:54,960

explain this and trying to persuade

750

00:28:59,510 --> 00:28:56,640

people that they need to continue giving

751
00:29:01,669 --> 00:28:59,520
us a lot of computer time and and money

752
00:29:04,630 --> 00:29:01,679
and effort to to allow us to figure out

753
00:29:05,909 --> 00:29:04,640
just exactly what is going on

754
00:29:07,510 --> 00:29:05,919
and

755
00:29:10,389 --> 00:29:07,520
in a sense this is only really the

756
00:29:12,630 --> 00:29:10,399
beginning voyager as i said has this in

757
00:29:15,590 --> 00:29:12,640
rather remarkable capacity to surprise

758
00:29:17,669 --> 00:29:15,600
at every turn and we're now going into a

759
00:29:19,590 --> 00:29:17,679
completely new environment it's truly

760
00:29:21,430 --> 00:29:19,600
alien it's not part of the solar system

761
00:29:23,510 --> 00:29:21,440
we've stepped into the galaxy we're out

762
00:29:25,990 --> 00:29:23,520
of our solar environment

763
00:29:28,549 --> 00:29:26,000

and what voyager is going to discover

764

00:29:30,870 --> 00:29:28,559

truly beggars the imagination i think

765

00:29:33,430 --> 00:29:30,880

that um at least for theorists we've got

766

00:29:35,190 --> 00:29:33,440

10 20 30 years of great fun and

767

00:29:37,669 --> 00:29:35,200

excitement ahead of us

768

00:29:40,630 --> 00:29:37,679

um and i'm looking forward to it it for

769

00:29:43,029 --> 00:29:40,640

me just turned on a personal note it's

770

00:29:45,430 --> 00:29:43,039

been truly remarkable i was in high

771

00:29:47,830 --> 00:29:45,440

school in a different country altogether

772

00:29:49,990 --> 00:29:47,840

when voyager was launched i did not know

773

00:29:52,149 --> 00:29:50,000

of ed i did not know don

774

00:29:54,710 --> 00:29:52,159

it's been a privilege to to get to know

775

00:29:56,549 --> 00:29:54,720

both of them of course but voyager has

776
00:29:58,870 --> 00:29:56,559
had this capacity not only to do

777
00:30:00,950 --> 00:29:58,880
fantastic really groundbreaking and

778
00:30:01,830 --> 00:30:00,960
remarkable science that

779
00:30:04,789 --> 00:30:01,840
um

780
00:30:06,470 --> 00:30:04,799
is is as as ed described

781
00:30:09,669 --> 00:30:06,480
ranks with the greatest voyages of

782
00:30:12,149 --> 00:30:09,679
discovery of of of humankind but it's

783
00:30:14,710 --> 00:30:12,159
also bridged generations of scientists

784
00:30:16,630 --> 00:30:14,720
um across and and as i said

785
00:30:18,870 --> 00:30:16,640
this is a mission that's almost as long

786
00:30:20,870 --> 00:30:18,880
as the space age itself and i've had the

787
00:30:23,510 --> 00:30:20,880
opportunity of

788
00:30:26,630 --> 00:30:23,520

witnessing in a sense the launch and now

789

00:30:29,269 --> 00:30:26,640

being at at what to me is a culturally

790

00:30:32,230 --> 00:30:29,279

and historically changing moment in in

791

00:30:34,230 --> 00:30:32,240

humankind we've put something into into

792

00:30:36,789 --> 00:30:34,240

interstellar space it's our first step

793

00:30:39,269 --> 00:30:36,799

into the galaxy and for a younger person

794

00:30:41,269 --> 00:30:39,279

i'm told my daughters tell me not

795

00:30:43,430 --> 00:30:41,279

that i'm not a young person anymore but

796

00:30:45,750 --> 00:30:43,440

for a younger person in any event it's

797

00:30:48,710 --> 00:30:45,760

it's it's it's quite humbling to be part

798

00:30:52,389 --> 00:30:50,310

so suzanne you're going to tell me why

799

00:30:54,630 --> 00:30:52,399

an obsolete piece of equipment still

800

00:30:57,269 --> 00:30:54,640

continues to function yeah

801
00:30:59,029 --> 00:30:57,279
thank you gary um well i'm i'm thrilled

802
00:31:00,630 --> 00:30:59,039
to be here wow that's about all i can

803
00:31:02,710 --> 00:31:00,640
say um

804
00:31:04,870 --> 00:31:02,720
i'll admit like gary i was in high

805
00:31:06,230 --> 00:31:04,880
school when voyager was launched and i

806
00:31:08,870 --> 00:31:06,240
was a little more concerned about

807
00:31:11,029 --> 00:31:08,880
getting my driver's license than i was

808
00:31:14,070 --> 00:31:11,039
about watching voyager launch at the

809
00:31:16,549 --> 00:31:14,080
time but i'm i'm excited to be here and

810
00:31:20,149 --> 00:31:16,559
talk to you today as the project manager

811
00:31:22,149 --> 00:31:20,159
and the key point i want to make is that

812
00:31:24,310 --> 00:31:22,159
this mission is not over i think you've

813
00:31:26,470 --> 00:31:24,320

heard all the my previous speakers tell

814

00:31:27,750 --> 00:31:26,480

you how much more science is out there

815

00:31:29,669 --> 00:31:27,760

yet to come

816

00:31:32,870 --> 00:31:29,679

and many many more discoveries are out

817

00:31:34,710 --> 00:31:32,880

there yet to come as well if we can roll

818

00:31:35,830 --> 00:31:34,720

the first graphic

819

00:31:38,149 --> 00:31:35,840

so

820

00:31:39,909 --> 00:31:38,159

voyager was launched at a time where it

821

00:31:44,470 --> 00:31:39,919

could take advantage of a unique

822

00:31:46,470 --> 00:31:44,480

trajectory which happens only 176 years

823

00:31:49,190 --> 00:31:46,480

it could reach all the outer planets in

824

00:31:50,630 --> 00:31:49,200

a 12-year time period uh the last time

825

00:31:53,830 --> 00:31:50,640

that could have happened was during

826

00:31:57,190 --> 00:31:53,840

thomas jefferson's administration so

827

00:31:58,870 --> 00:31:57,200

uh voyager 1 uh went by

828

00:32:01,590 --> 00:31:58,880

uh jupiter and saturn that was the

829

00:32:03,830 --> 00:32:01,600

original mission and then voyager 2 was

830

00:32:05,350 --> 00:32:03,840

able to continue on to uranus and

831

00:32:07,269 --> 00:32:05,360

neptune

832

00:32:10,149 --> 00:32:07,279

between the two voyager spacecraft they

833

00:32:11,269 --> 00:32:10,159

discovered 23 moons of the outer giant

834

00:32:14,389 --> 00:32:11,279

planets

835

00:32:17,990 --> 00:32:14,399

and today voyager is traveling away from

836

00:32:19,990 --> 00:32:18,000

us in interstellar space at over 38 000

837

00:32:23,110 --> 00:32:20,000

miles per hour

838

00:32:26,070 --> 00:32:23,120

now um the voyager spacecraft is old

839

00:32:27,990 --> 00:32:26,080

uh and because of that uh the science

840

00:32:31,590 --> 00:32:28,000

team who works on it are what we like to

841

00:32:34,389 --> 00:32:31,600

call well seasoned and if i can have the

842

00:32:37,430 --> 00:32:34,399

slide the team one slide

843

00:32:39,509 --> 00:32:37,440

this is an image taken from 1972. it's

844

00:32:41,830 --> 00:32:39,519

the first science steering group meeting

845

00:32:44,310 --> 00:32:41,840

held at the jet propulsion laboratory

846

00:32:46,870 --> 00:32:44,320

right after the project was started

847

00:32:48,870 --> 00:32:46,880

uh you could probably pick out ed stone

848

00:32:50,389 --> 00:32:48,880

he's the in the front row the second

849

00:32:51,509 --> 00:32:50,399

from the left his hair is a little

850

00:32:53,909 --> 00:32:51,519

darker and

851
00:32:55,350 --> 00:32:53,919
uh you know he's looking pretty good as

852
00:32:57,909 --> 00:32:55,360
well as the rest of the science team

853
00:32:59,110 --> 00:32:57,919
there and if i can have the next steam

854
00:33:01,830 --> 00:32:59,120
picture

855
00:33:04,789 --> 00:33:01,840
you'll see uh how we look today okay so

856
00:33:07,750 --> 00:33:04,799
this image was taken uh on monday

857
00:33:10,310 --> 00:33:07,760
and uh it's nearly 40 years after the

858
00:33:12,549 --> 00:33:10,320
previous image and

859
00:33:15,029 --> 00:33:12,559
this is the science team there's about

860
00:33:17,110 --> 00:33:15,039
12 engineers back at jpl who operate

861
00:33:18,710 --> 00:33:17,120
both spacecraft

862
00:33:20,549 --> 00:33:18,720
and they're uh they've been with the

863
00:33:22,549 --> 00:33:20,559

project nearly as long as all the

864

00:33:24,389 --> 00:33:22,559

scientists and and what i can tell you

865

00:33:26,789 --> 00:33:24,399

about this group is that they are

866

00:33:29,269 --> 00:33:26,799

extremely passionate about their science

867

00:33:31,110 --> 00:33:29,279

they are has passionate today

868

00:33:32,710 --> 00:33:31,120

they argue they banter at each other

869

00:33:34,389 --> 00:33:32,720

they go back and forth at it in these

870

00:33:35,909 --> 00:33:34,399

science team meetings and

871

00:33:38,950 --> 00:33:35,919

they're just as passionate today as they

872

00:33:41,029 --> 00:33:38,960

were in 1972.

873

00:33:43,430 --> 00:33:41,039

so one of the things i want to

874

00:33:45,909 --> 00:33:43,440

give you a sense for is the technology

875

00:33:47,909 --> 00:33:45,919

and the age of the voyager spacecraft so

876

00:33:51,509 --> 00:33:47,919

the voyager spacecraft

877

00:33:54,230 --> 00:33:51,519

has only 68 kilobytes of memory on board

878

00:33:56,710 --> 00:33:54,240

now i'm going to pull out my smartphone

879

00:33:59,990 --> 00:33:56,720

whichever all of you have okay this has

880

00:34:02,389 --> 00:34:00,000

240 000 times more memory than the

881

00:34:03,509 --> 00:34:02,399

voyager spacecraft

882

00:34:05,830 --> 00:34:03,519

okay

883

00:34:06,789 --> 00:34:05,840

but we it's the little spacecraft that

884

00:34:08,950 --> 00:34:06,799

could

885

00:34:10,149 --> 00:34:08,960

you know we keep on going

886

00:34:12,230 --> 00:34:10,159

um

887

00:34:14,710 --> 00:34:12,240

we talk uh communicate with the

888

00:34:15,750 --> 00:34:14,720

spacecraft every day both spacecraft

889

00:34:18,790 --> 00:34:15,760

every day

890

00:34:21,190 --> 00:34:18,800

and uh we use the deep space network

891

00:34:24,069 --> 00:34:21,200

that's run by nasa

892

00:34:26,470 --> 00:34:24,079

and really i would say the voyager and

893

00:34:30,629 --> 00:34:26,480

the dsn have grown up together the dsn

894

00:34:34,950 --> 00:34:33,510

voyager is currently 11.6 billion miles

895

00:34:38,389 --> 00:34:34,960

away from us

896

00:34:41,750 --> 00:34:38,399

and it uh the signal from voyager to the

897

00:34:43,430 --> 00:34:41,760

earth takes 17 hours and 22 minutes one

898

00:34:46,829 --> 00:34:43,440

way

899

00:34:48,869 --> 00:34:46,839

okay voyager transmits with a 22 watt

900

00:34:51,510 --> 00:34:48,879

transmitter okay that's about the size

901
00:34:53,750 --> 00:34:51,520
of your refrigerator light bulb

902
00:34:55,990 --> 00:34:53,760
when that signal comes down and the dsn

903
00:35:00,630 --> 00:34:56,000
picks it up it's one tenth of a

904
00:35:06,069 --> 00:35:03,190
now um

905
00:35:06,950 --> 00:35:06,079
uh back in february we were fortunate to

906
00:35:09,670 --> 00:35:06,960
have

907
00:35:11,910 --> 00:35:09,680
another observatory the very long

908
00:35:15,030 --> 00:35:11,920
baseline array which is operated by the

909
00:35:18,470 --> 00:35:15,040
national radio astronomy observatory try

910
00:35:20,550 --> 00:35:18,480
to look for voyager's radio signal

911
00:35:23,270 --> 00:35:20,560
at uh voyager was eleven and a half

912
00:35:25,270 --> 00:35:23,280
billion miles away last february

913
00:35:26,550 --> 00:35:25,280

and the viba went out there and looked

914

00:35:28,390 --> 00:35:26,560

for the signal if you can bring up the

915

00:35:30,630 --> 00:35:28,400

next graphic

916

00:35:34,390 --> 00:35:30,640

they were able to see

917

00:35:37,510 --> 00:35:34,400

a blue speck and this image represents

918

00:35:39,670 --> 00:35:37,520

the voyager radio signal as seen by the

919

00:35:43,349 --> 00:35:39,680

world's most sensitive

920

00:35:46,950 --> 00:35:43,359

ground-based telescope it's just of spec

921

00:35:48,870 --> 00:35:46,960

in amongst the sea of darkness

922

00:35:51,109 --> 00:35:48,880

now i mentioned earlier that

923

00:35:52,790 --> 00:35:51,119

this mission can continue for several

924

00:35:55,109 --> 00:35:52,800

more years

925

00:35:57,349 --> 00:35:55,119

we use radioisotope thermoelectric

926
00:36:00,470 --> 00:35:57,359
generators they were provided by the

927
00:36:04,310 --> 00:36:01,430
and

928
00:36:05,750 --> 00:36:04,320
they decay at four watts per year in

929
00:36:08,630 --> 00:36:05,760
other words they lose four watts of

930
00:36:10,390 --> 00:36:08,640
power per year so as a as a project

931
00:36:12,310 --> 00:36:10,400
manager and the engineers on voyager we

932
00:36:15,109 --> 00:36:12,320
have to be very careful to manage that

933
00:36:17,109 --> 00:36:15,119
power source so that we can continue to

934
00:36:18,230 --> 00:36:17,119
operate the instruments for as long as

935
00:36:21,109 --> 00:36:18,240
possible

936
00:36:23,750 --> 00:36:21,119
and we have enough power to operate the

937
00:36:25,750 --> 00:36:23,760
fields and particles instruments

938
00:36:27,589 --> 00:36:25,760

um which are taking the current

939

00:36:30,470 --> 00:36:27,599

interstellar data

940

00:36:32,470 --> 00:36:30,480

out till the year 2020 so that's seven

941

00:36:35,109 --> 00:36:32,480

more years we can operate these

942

00:36:37,030 --> 00:36:35,119

instruments and then after the year 2020

943

00:36:37,910 --> 00:36:37,040

we'll be turning off one instrument at a

944

00:36:39,990 --> 00:36:37,920

time

945

00:36:41,990 --> 00:36:40,000

until the year 2025 when all the

946

00:36:45,190 --> 00:36:42,000

instruments will go off but that gives

947

00:36:47,030 --> 00:36:45,200

us a good 13 14 more years to operate

948

00:36:48,870 --> 00:36:47,040

the voyager spacecraft and get science

949

00:36:51,030 --> 00:36:48,880

data back from them

950

00:36:53,510 --> 00:36:51,040

we can operate the spacecraft about 10

951
00:36:55,349 --> 00:36:53,520
more years afterwards

952
00:36:57,430 --> 00:36:55,359
if we just want to take down engineering

953
00:36:59,910 --> 00:36:57,440
data

954
00:37:01,750 --> 00:36:59,920
so where is voyager going well if we can

955
00:37:04,630 --> 00:37:01,760
have the next graphic

956
00:37:09,030 --> 00:37:04,640
that's where voyager is going okay

957
00:37:11,109 --> 00:37:09,040
that star is ac plus 79 38 88

958
00:37:14,069 --> 00:37:11,119
voyager is on its way to a close

959
00:37:16,790 --> 00:37:14,079
approach with it uh in about 40 000

960
00:37:18,870 --> 00:37:16,800
years it's going to come within 1.7

961
00:37:20,710 --> 00:37:18,880
light years of this star

962
00:37:23,670 --> 00:37:20,720
and it will swing by it and it will

963
00:37:27,349 --> 00:37:23,680

continue to orbit around the center of

964

00:37:30,310 --> 00:37:28,470

and finally

965

00:37:31,589 --> 00:37:30,320

i just want to

966

00:37:34,150 --> 00:37:31,599

comment that

967

00:37:36,790 --> 00:37:34,160

i really feel the people who

968

00:37:39,349 --> 00:37:36,800

had the vision to create voyager

969

00:37:40,150 --> 00:37:39,359

who uh built it and who sent it on its

970

00:37:42,069 --> 00:37:40,160

way

971

00:37:43,829 --> 00:37:42,079

they were they just had an extraordinary

972

00:37:45,030 --> 00:37:43,839

vision about the discovery in the

973

00:37:48,950 --> 00:37:45,040

adventure

974

00:37:50,870 --> 00:37:48,960

and uh voyager was built for scientists

975

00:37:53,510 --> 00:37:50,880

but

976

00:37:55,829 --> 00:37:53,520

it's really for all of us

977

00:37:58,230 --> 00:37:55,839

voyager contains on it

978

00:38:00,710 --> 00:37:58,240

each voyager has a gold record

979

00:38:02,630 --> 00:38:00,720

this gold record was designed by carl

980

00:38:04,550 --> 00:38:02,640

sagan and his team

981

00:38:05,910 --> 00:38:04,560

and on this gold record

982

00:38:08,390 --> 00:38:05,920

are music

983

00:38:10,230 --> 00:38:08,400

and uh greetings

984

00:38:12,950 --> 00:38:10,240

and sounds

985

00:38:14,950 --> 00:38:12,960

and even images of the planet earth from

986

00:38:17,829 --> 00:38:14,960

all over the planet earth

987

00:38:19,670 --> 00:38:17,839

and it's really a time capsule of us you

988

00:38:22,069 --> 00:38:19,680

know this is this is us contained in

989

00:38:24,950 --> 00:38:22,079

this record and now the voyager and

990

00:38:27,510 --> 00:38:24,960

particularly voyager 1 is carrying this

991

00:38:29,670 --> 00:38:27,520

time capsule of us into interstellar

992

00:38:32,390 --> 00:38:29,680

space and we're traveling along with

993

00:38:34,150 --> 00:38:32,400

voyager as it continues on this journey

994

00:38:35,510 --> 00:38:34,160

of discovery

995

00:38:36,390 --> 00:38:35,520

so dwayne i'm going to give it back to

996

00:38:39,589 --> 00:38:36,400

you

997

00:38:41,750 --> 00:38:39,599

clearly

998

00:38:44,150 --> 00:38:41,760

an incredible team

999

00:38:46,310 --> 00:38:44,160

and i want to acknowledge

1000

00:38:47,910 --> 00:38:46,320

the deputy associate administrator for

1001
00:38:50,950 --> 00:38:47,920
space communications and navigation

1002
00:38:52,230 --> 00:38:50,960
scanned boundary eunice uh

1003
00:38:54,630 --> 00:38:52,240
taking care and listening to the

1004
00:38:57,109 --> 00:38:54,640
spacecraft but i believe these this team

1005
00:38:58,390 --> 00:38:57,119
and all the folks many in this room and

1006
00:38:59,990 --> 00:38:58,400
listening to this program let's give

1007
00:39:06,150 --> 00:39:00,000
them a round of applause great job

1008
00:39:09,030 --> 00:39:07,510
okay here's how we're going to do this

1009
00:39:10,870 --> 00:39:09,040
we're going to go to the phone lines but

1010
00:39:12,630 --> 00:39:10,880
i want to let our folks out there

1011
00:39:14,710 --> 00:39:12,640
watching and i'm hearing my ears there a

1012
00:39:15,829 --> 00:39:14,720
lot of you all out there buzzing about

1013
00:39:17,990 --> 00:39:15,839

this news

1014

00:39:19,750 --> 00:39:18,000

uh please stay with us because there is

1015

00:39:21,349 --> 00:39:19,760

an incredible video that we're going to

1016

00:39:23,510 --> 00:39:21,359

end the program with so don't go away

1017

00:39:25,670 --> 00:39:23,520

yet we're going to go to the phone lines

1018

00:39:27,990 --> 00:39:25,680

we're going to take a few questions a

1019

00:39:29,349 --> 00:39:28,000

lot of the media around the world have

1020

00:39:31,990 --> 00:39:29,359

their stories and we want to thank

1021

00:39:33,270 --> 00:39:32,000

working with science magazine and of

1022

00:39:36,069 --> 00:39:33,280

course all of the work from jet

1023

00:39:38,710 --> 00:39:36,079

propulsion laboratory and again the team

1024

00:39:40,150 --> 00:39:38,720

so let's uh go to the phone lines

1025

00:39:41,829 --> 00:39:40,160

and then we're going to take a couple of

1026
00:39:43,990 --> 00:39:41,839
questions from social media and then

1027
00:39:46,069 --> 00:39:44,000
we're going to show the video

1028
00:39:48,310 --> 00:39:46,079
let me take one

1029
00:39:50,390 --> 00:39:48,320
question from social media

1030
00:39:52,150 --> 00:39:50,400
i think we want to try to go there first

1031
00:39:54,069 --> 00:39:52,160
this is my colleague

1032
00:39:56,310 --> 00:39:54,079
jason townsend on the case our manager

1033
00:39:58,150 --> 00:39:56,320
for social media jason what's going on

1034
00:39:59,670 --> 00:39:58,160
out in the social media world indeed

1035
00:40:01,510 --> 00:39:59,680
there's lots of buzz today all over

1036
00:40:03,990 --> 00:40:01,520
social media about this announcement so

1037
00:40:05,910 --> 00:40:04,000
first question comes from crow robot

1038
00:40:08,150 --> 00:40:05,920

has voyager's path pretty well met

1039

00:40:10,150 --> 00:40:08,160

expectations or have unknown or unseen

1040

00:40:14,069 --> 00:40:10,160

gravitational sources modified its

1041

00:40:18,710 --> 00:40:16,630

its course is very accurately determined

1042

00:40:21,990 --> 00:40:18,720

by the gravitational forces we're aware

1043

00:40:26,309 --> 00:40:22,950

okay

1044

00:40:27,589 --> 00:40:26,319

social media we're going to now go to

1045

00:40:29,589 --> 00:40:27,599

the phone line

1046

00:40:31,589 --> 00:40:29,599

and i think we're going uh to san

1047

00:40:33,670 --> 00:40:31,599

francisco david perlman san francisco

1048

00:40:35,190 --> 00:40:33,680

chronicle david

1049

00:40:38,710 --> 00:40:35,200

well thanks very much for taking the

1050

00:40:40,470 --> 00:40:38,720

call uh for don garnett uh could you

1051

00:40:44,150 --> 00:40:40,480

explain the

1052

00:40:47,910 --> 00:40:44,160

uh results of the plasma oscillation in

1053

00:40:50,870 --> 00:40:47,920

october and november 2012 and april may

1054

00:40:53,910 --> 00:40:50,880

2013 and were they both the results of a

1055

00:40:54,870 --> 00:40:53,920

cme from the sun or what what's all that

1056

00:40:56,870 --> 00:40:54,880

about

1057

00:40:58,230 --> 00:40:56,880

uh yes i can comment on that

1058

00:41:02,790 --> 00:40:58,240

uh the

1059

00:41:05,349 --> 00:41:02,800

the last event the uh april may 2013

1060

00:41:07,910 --> 00:41:05,359

we're pretty sure that it started with

1061

00:41:10,150 --> 00:41:07,920

the st patrick's day event which was in

1062

00:41:11,829 --> 00:41:10,160

march of 2012. i don't remember the

1063

00:41:13,990 --> 00:41:11,839

exact date

1064

00:41:15,990 --> 00:41:14,000

because the

1065

00:41:17,670 --> 00:41:16,000

energetic particle instrument tom

1066

00:41:19,670 --> 00:41:17,680

kermigus is an instrument he's here he

1067

00:41:22,470 --> 00:41:19,680

could comment if you

1068

00:41:24,069 --> 00:41:22,480

saw an effect there that had the right

1069

00:41:25,829 --> 00:41:24,079

timing

1070

00:41:28,870 --> 00:41:25,839

now the other event we've had more

1071

00:41:30,390 --> 00:41:28,880

trouble uh identifying just what it was

1072

00:41:32,230 --> 00:41:30,400

on the sun

1073

00:41:33,910 --> 00:41:32,240

that produced that event i think i'd

1074

00:41:35,910 --> 00:41:33,920

have to say that's still under study

1075

00:41:37,589 --> 00:41:35,920

although there are some interesting

1076
00:41:39,510 --> 00:41:37,599
things that happened in the spacecraft

1077
00:41:41,270 --> 00:41:39,520
that are not yet reported i believe

1078
00:41:42,950 --> 00:41:41,280
that's the way i put it

1079
00:41:45,589 --> 00:41:42,960
i might comment that

1080
00:41:47,990 --> 00:41:45,599
because the earth moves around the sun

1081
00:41:49,910 --> 00:41:48,000
we are not always in the ideal position

1082
00:41:51,670 --> 00:41:49,920
to see something headed toward voyager

1083
00:41:53,430 --> 00:41:51,680
in fact in december we're on the

1084
00:41:54,950 --> 00:41:53,440
opposite side of the sun from from

1085
00:41:57,030 --> 00:41:54,960
voyager so something from the sun

1086
00:42:01,109 --> 00:41:57,040
heading out the voyager we could not see

1087
00:42:06,790 --> 00:42:04,150
our next question is from jackie goddard

1088
00:42:09,430 --> 00:42:06,800

from the times of london

1089

00:42:12,150 --> 00:42:09,440

jackie hello and uh congratulations it's

1090

00:42:13,829 --> 00:42:12,160

a question for dr stone um at a tele

1091

00:42:16,150 --> 00:42:13,839

conference like this last year when you

1092

00:42:17,750 --> 00:42:16,160

said that voyager doran was nearing the

1093

00:42:19,430 --> 00:42:17,760

edge of the heliosphere you said that

1094

00:42:21,190 --> 00:42:19,440

you didn't know how you would celebrate

1095

00:42:22,470 --> 00:42:21,200

when the moment finally came but you

1096

00:42:25,190 --> 00:42:22,480

knew that you would probably at least

1097

00:42:27,829 --> 00:42:25,200

hold a meeting um beyond just holding a

1098

00:42:29,510 --> 00:42:27,839

meeting how did you celebrate

1099

00:42:31,829 --> 00:42:29,520

well we did hold the meeting the fact

1100

00:42:33,829 --> 00:42:31,839

we've held three meetings since the

1101

00:42:36,309 --> 00:42:33,839

since the plasma wave observations

1102

00:42:39,109 --> 00:42:36,319

occurred because uh this is obviously an

1103

00:42:41,990 --> 00:42:39,119

exciting milestone for for all of us and

1104

00:42:43,430 --> 00:42:42,000

i think uh we're looking forward to uh

1105

00:42:45,109 --> 00:42:43,440

further meetings coming up with the

1106

00:42:47,190 --> 00:42:45,119

american geophysical union meeting in

1107

00:42:49,190 --> 00:42:47,200

december so somewhere along the line we

1108

00:42:51,589 --> 00:42:49,200

will really celebrate but individually

1109

00:42:53,349 --> 00:42:51,599

we're all overjoyed

1110

00:42:55,109 --> 00:42:53,359

i might comment on that actually i

1111

00:43:00,710 --> 00:42:55,119

considered those meetings to be

1112

00:43:06,309 --> 00:43:03,349

okay now we uh have bill harwood cbs

1113

00:43:08,230 --> 00:43:06,319

news bill greetings

1114

00:43:10,309 --> 00:43:08,240

hey thank you very much a question for

1115

00:43:12,710 --> 00:43:10,319

ed what about voyager 2 when would you

1116

00:43:14,630 --> 00:43:12,720

expect it to uh

1117

00:43:15,990 --> 00:43:14,640

to get there and what will it bring to

1118

00:43:18,069 --> 00:43:16,000

the table instrument wise that you

1119

00:43:20,630 --> 00:43:18,079

didn't have a voyager 1 thing well first

1120

00:43:22,470 --> 00:43:20,640

of all voyager 1 is headed up in the

1121

00:43:25,030 --> 00:43:22,480

toward the north and pretty

1122

00:43:27,910 --> 00:43:25,040

much in the nose word direction voyager

1123

00:43:29,829 --> 00:43:27,920

2 is sort of down here uh in the south

1124

00:43:32,710 --> 00:43:29,839

and somewhat off to the flank so it's a

1125

00:43:35,109 --> 00:43:32,720

different part of the heliosphere

1126

00:43:36,710 --> 00:43:35,119

and it's in c and we do have a working

1127

00:43:38,710 --> 00:43:36,720

solar wind instrument so we're actually

1128

00:43:40,790 --> 00:43:38,720

measuring the plasma density speed and

1129

00:43:43,670 --> 00:43:40,800

temperature we will have that when we

1130

00:43:46,870 --> 00:43:43,680

cross the heliopause on voyager 2.

1131

00:43:50,230 --> 00:43:46,880

uh in terms of timing uh we don't know

1132

00:43:52,150 --> 00:43:50,240

for sure but it was it took three years

1133

00:43:54,069 --> 00:43:52,160

more for voyager 2 to find the

1134

00:43:55,990 --> 00:43:54,079

termination shotgun voyager 1 so you

1135

00:43:58,069 --> 00:43:56,000

might say another three years for

1136

00:44:00,550 --> 00:43:58,079

voyager 2 to find the heliopause to

1137

00:44:05,030 --> 00:44:00,560

first order but in fact as usual the

1138

00:44:11,190 --> 00:44:07,510

okay next caller is clara moskowitz from

1139

00:44:13,349 --> 00:44:11,200

scientific american clara

1140

00:44:14,710 --> 00:44:13,359

yes hi thanks for taking my call i was

1141

00:44:16,950 --> 00:44:14,720

hoping somebody could talk in a little

1142

00:44:19,190 --> 00:44:16,960

bit more detail about the origin of the

1143

00:44:20,829 --> 00:44:19,200

interstellar plasma what it's made up of

1144

00:44:25,270 --> 00:44:20,839

and where we think it comes

1145

00:44:27,589 --> 00:44:25,280

from well the interstellar plasma is

1146

00:44:29,990 --> 00:44:27,599

created by the explosion of stars so

1147

00:44:30,790 --> 00:44:30,000

there's a there's a stellar cycle where

1148

00:44:32,790 --> 00:44:30,800

the

1149

00:44:35,109 --> 00:44:32,800

interstellar medium collapses to make a

1150

00:44:36,950 --> 00:44:35,119

new star if it's so massive that star

1151

00:44:39,109 --> 00:44:36,960

has the life of only about a million

1152

00:44:40,950 --> 00:44:39,119

years and it blows up and puts all of

1153

00:44:43,030 --> 00:44:40,960

its stuff back out into the interstellar

1154

00:44:45,670 --> 00:44:43,040

medium so the interstellar medium is

1155

00:44:47,910 --> 00:44:45,680

constantly replenished by exploding

1156

00:44:51,349 --> 00:44:47,920

stars we do know there were a set of

1157

00:44:54,550 --> 00:44:51,359

exploding stars near the earth 5 to 10

1158

00:44:57,030 --> 00:44:54,560

to 15 million years ago and the material

1159

00:44:59,670 --> 00:44:57,040

we're currently surrounded by is stuff

1160

00:45:04,230 --> 00:44:59,680

that came from those explosions plus

1161

00:45:09,270 --> 00:45:06,390

next question is from kelly beatty

1162

00:45:12,069 --> 00:45:09,280

sky and telescope kelly

1163

00:45:13,510 --> 00:45:12,079

yeah yeah thank you very much and and uh

1164

00:45:16,550 --> 00:45:13,520

it's a great day i'm i'm a little

1165

00:45:19,670 --> 00:45:16,560

confused by the timeline here um

1166

00:45:22,150 --> 00:45:19,680

about a month ago uh the article came

1167

00:45:24,309 --> 00:45:22,160

out by mark swiss back at all that said

1168

00:45:26,230 --> 00:45:24,319

that they thought that voyager was in

1169

00:45:28,790 --> 00:45:26,240

the helios i mean in the interstellar

1170

00:45:30,870 --> 00:45:28,800

medium and ted stone came out with a

1171

00:45:33,430 --> 00:45:30,880

statement saying well it's a little

1172

00:45:35,430 --> 00:45:33,440

typical at this point yet you had the

1173

00:45:37,670 --> 00:45:35,440

plasma wave data at that point so can

1174

00:45:39,829 --> 00:45:37,680

you kind of walk me through the timeline

1175

00:45:41,670 --> 00:45:39,839

of what you knew when you knew it

1176

00:45:44,230 --> 00:45:41,680

well i think don you should talk about

1177

00:45:45,670 --> 00:45:44,240

the time it took to get the data down

1178

00:45:48,710 --> 00:45:45,680

someone was on the tape recorder in the

1179

00:45:51,270 --> 00:45:48,720

spacecraft uh and the time it took to us

1180

00:45:53,589 --> 00:45:51,280

to to really make sure this was plasma

1181

00:45:55,670 --> 00:45:53,599

wave data and not radio data

1182

00:45:57,990 --> 00:45:55,680

right yes well it uh

1183

00:46:00,150 --> 00:45:58,000

the data the high resolution data we get

1184

00:46:02,550 --> 00:46:00,160

the type of thing that you we played the

1185

00:46:04,870 --> 00:46:02,560

sounds they're stored on the taper

1186

00:46:06,550 --> 00:46:04,880

spacecraft tape recorder and it can be

1187

00:46:08,630 --> 00:46:06,560

up to six months they only play it back

1188

00:46:10,069 --> 00:46:08,640

every six months

1189

00:46:12,470 --> 00:46:10,079

but

1190

00:46:14,230 --> 00:46:12,480

i think i would also comment or maybe ed

1191

00:46:16,150 --> 00:46:14,240

you'd want to comment it i believe the

1192

00:46:18,230 --> 00:46:16,160

swiss deck paper was basically a theory

1193

00:46:20,309 --> 00:46:18,240

paper and as a matter of fact our paper

1194

00:46:21,829 --> 00:46:20,319

was submitted at least almost a month

1195

00:46:23,109 --> 00:46:21,839

before there so they just got through

1196

00:46:25,829 --> 00:46:23,119

the

1197

00:46:27,670 --> 00:46:25,839

review cycle faster than we did

1198

00:46:31,190 --> 00:46:27,680

so if you want to talk about the timing

1199

00:46:34,390 --> 00:46:32,550

okay we're going to take a couple more

1200

00:46:35,910 --> 00:46:34,400

questions then a couple of more from

1201
00:46:37,190 --> 00:46:35,920
social media and we're going to try to

1202
00:46:39,589 --> 00:46:37,200
close out the top of the aisle but

1203
00:46:45,910 --> 00:46:39,599
remember stay tuned for that video

1204
00:46:50,870 --> 00:46:48,550
oh collin hi guys thanks again for

1205
00:46:52,230 --> 00:46:50,880
actually doing this and yeah a great job

1206
00:46:54,069 --> 00:46:52,240
getting it out there it's a big moment

1207
00:46:55,750 --> 00:46:54,079
for all of us um i just had a quick

1208
00:46:57,190 --> 00:46:55,760
question now that you're

1209
00:46:59,670 --> 00:46:57,200
you're actually in an interstellar space

1210
00:47:03,829 --> 00:47:02,150
yeah what do you expect to sort of look

1211
00:47:05,190 --> 00:47:03,839
for what are some of the questions that

1212
00:47:06,550 --> 00:47:05,200
you're going to be trying to answer out

1213
00:47:09,510 --> 00:47:06,560

there i mean i know it's an entirely new

1214

00:47:11,109 --> 00:47:09,520

environment so update for sure but like

1215

00:47:13,430 --> 00:47:11,119

yeah what are some of the things that

1216

00:47:16,950 --> 00:47:13,440

that that you'll be looking for as this

1217

00:47:19,990 --> 00:47:16,960

book continues to send data back to us

1218

00:47:21,670 --> 00:47:20,000

gary i can i can comment on that well as

1219

00:47:23,829 --> 00:47:21,680

i showed there where

1220

00:47:25,829 --> 00:47:23,839

as voyageur is moving out the density is

1221

00:47:26,710 --> 00:47:25,839

slowly increasing

1222

00:47:27,990 --> 00:47:26,720

and

1223

00:47:30,069 --> 00:47:28,000

well

1224

00:47:32,230 --> 00:47:30,079

there could be various models for that

1225

00:47:34,390 --> 00:47:32,240

we saw a similar effect with the radio

1226

00:47:37,349 --> 00:47:34,400

emission 20 years ago and in that paper

1227

00:47:38,870 --> 00:47:37,359

i described it as a pile-up effect that

1228

00:47:47,270 --> 00:47:38,880

the

1229

00:47:49,030 --> 00:47:47,280

paper by bronoff

1230

00:47:51,109 --> 00:47:49,040

that suggested that

1231

00:47:52,549 --> 00:47:51,119

for a simple explanation that i've been

1232

00:47:54,390 --> 00:47:52,559

telling some of the media it's like a

1233

00:47:55,990 --> 00:47:54,400

snow plow going through the snow and

1234

00:47:57,349 --> 00:47:56,000

piles up ahead

1235

00:47:58,950 --> 00:47:57,359

but i'm sure that there's more

1236

00:48:01,349 --> 00:47:58,960

sophisticated

1237

00:48:03,510 --> 00:48:01,359

explanations than i actually know that

1238

00:48:06,470 --> 00:48:03,520

gary zank has one

1239

00:48:08,150 --> 00:48:06,480

would you like to take the ball now well

1240

00:48:10,069 --> 00:48:08,160

i can certainly take the ball i'm not

1241

00:48:11,910 --> 00:48:10,079

going to continue your explanation or

1242

00:48:13,829 --> 00:48:11,920

discussion further in that regard don

1243

00:48:16,710 --> 00:48:13,839

but to answer the question that was

1244

00:48:18,630 --> 00:48:16,720

asked in part um there is a great deal

1245

00:48:20,710 --> 00:48:18,640

of very interesting science that that

1246

00:48:21,670 --> 00:48:20,720

really opens up here for one

1247

00:48:23,670 --> 00:48:21,680

um

1248

00:48:25,589 --> 00:48:23,680

one one of the things i think that will

1249

00:48:27,910 --> 00:48:25,599

be of of tremendous interest and

1250

00:48:30,309 --> 00:48:27,920

importance is to study more accurately

1251

00:48:32,309 --> 00:48:30,319

the galactic cosmic rays the galactic

1252

00:48:35,349 --> 00:48:32,319

cosmic rays of course are created in the

1253

00:48:36,390 --> 00:48:35,359

um probably in supernova remnant driven

1254

00:48:38,230 --> 00:48:36,400

shocks

1255

00:48:39,829 --> 00:48:38,240

and and so

1256

00:48:41,829 --> 00:48:39,839

in order to study those we've always

1257

00:48:43,829 --> 00:48:41,839

studied them from within the heliosphere

1258

00:48:45,750 --> 00:48:43,839

and that means studying

1259

00:48:47,510 --> 00:48:45,760

the particles these and very very

1260

00:48:49,990 --> 00:48:47,520

energetic galactic cosmic rays when

1261

00:48:52,549 --> 00:48:50,000

they're very strongly modulated by the

1262

00:48:55,190 --> 00:48:52,559

by the presence of the solar wind and so

1263

00:48:57,190 --> 00:48:55,200

being outside the the heliosphere allows

1264

00:48:59,670 --> 00:48:57,200

us an opportunity to in a sense look at

1265

00:49:01,990 --> 00:48:59,680

the undiluted galactic cosmic ray

1266

00:49:04,069 --> 00:49:02,000

spectrum the undiluted galactic cosmic

1267

00:49:06,230 --> 00:49:04,079

rays so that will tell us a great deal

1268

00:49:08,950 --> 00:49:06,240

more about the interstellar medium at

1269

00:49:11,190 --> 00:49:08,960

very distant distant locations it'll

1270

00:49:12,790 --> 00:49:11,200

tell us about how the galactic cosmic

1271

00:49:14,470 --> 00:49:12,800

rays propagate through this very

1272

00:49:16,470 --> 00:49:14,480

complicated interstellar medium the

1273

00:49:18,069 --> 00:49:16,480

interstellar medium is a mixture of hot

1274

00:49:20,950 --> 00:49:18,079

warm

1275

00:49:23,109 --> 00:49:20,960

ionized partially ionized not ionized

1276

00:49:24,549 --> 00:49:23,119

gases and

1277

00:49:26,390 --> 00:49:24,559

and of course it'll also allow us to

1278

00:49:28,390 --> 00:49:26,400

study a great deal about the nature of

1279

00:49:30,790 --> 00:49:28,400

the fluctuations and the magnetic field

1280

00:49:33,270 --> 00:49:30,800

in the in in the interstellar medium and

1281

00:49:35,670 --> 00:49:33,280

so already in some respects i believe

1282

00:49:38,069 --> 00:49:35,680

voyager is probably and tom crumijus has

1283

00:49:39,829 --> 00:49:38,079

reported on this showing up a number of

1284

00:49:41,750 --> 00:49:39,839

surprises in in the nature of the

1285

00:49:43,190 --> 00:49:41,760

galactic and anomalous cosmic rays the

1286

00:49:44,950 --> 00:49:43,200

anomalous cosmic rays of course

1287

00:49:47,109 --> 00:49:44,960

disappeared but where did they disappear

1288

00:49:49,109 --> 00:49:47,119

to and what effect have they on the on

1289

00:49:51,030 --> 00:49:49,119

the local interstellar medium so that's

1290

00:49:53,109 --> 00:49:51,040

going to be a very large area of study

1291

00:49:55,829 --> 00:49:53,119

another very interesting area that that

1292

00:49:57,670 --> 00:49:55,839

that is worth worth looking at closely

1293

00:49:59,829 --> 00:49:57,680

is certainly we're in the interstellar

1294

00:50:02,950 --> 00:49:59,839

medium but the interstellar medium is

1295

00:50:05,750 --> 00:50:02,960

itself affected by the by the solar wind

1296

00:50:09,829 --> 00:50:05,760

and its properties and so there are very

1297

00:50:12,309 --> 00:50:09,839

complicated um processes that that that

1298

00:50:15,270 --> 00:50:12,319

lead to the deposition of momentum and

1299

00:50:17,270 --> 00:50:15,280

energy into the very local

1300

00:50:19,829 --> 00:50:17,280

environment the very local interstellar

1301
00:50:22,150 --> 00:50:19,839
environment and one example is is the

1302
00:50:23,910 --> 00:50:22,160
propagation of the shock waves that were

1303
00:50:26,470 --> 00:50:23,920
driven off by the sun into the

1304
00:50:28,309 --> 00:50:26,480
interstellar medium how do those

1305
00:50:30,150 --> 00:50:28,319
propagate what do they look like what is

1306
00:50:31,670 --> 00:50:30,160
the nature of the energy and momentum

1307
00:50:33,349 --> 00:50:31,680
transfer from the sun to the

1308
00:50:35,270 --> 00:50:33,359
interstellar medium there are other

1309
00:50:38,230 --> 00:50:35,280
processes at work associated with the

1310
00:50:40,790 --> 00:50:38,240
deposition of energetic neutral atoms

1311
00:50:43,030 --> 00:50:40,800
into the local interstellar medium and

1312
00:50:44,870 --> 00:50:43,040
that has a tangible effect on the nature

1313
00:50:48,069 --> 00:50:44,880

of the interstellar medium so all of

1314

00:50:49,670 --> 00:50:48,079

that needs to be considered and explored

1315

00:50:51,990 --> 00:50:49,680

and then of course there's just the very

1316

00:50:54,950 --> 00:50:52,000

basic questions of what are the what is

1317

00:50:57,190 --> 00:50:54,960

the nature of the interstellar plasma

1318

00:51:00,150 --> 00:50:57,200

proton and electron distribution

1319

00:51:02,069 --> 00:51:00,160

functions and how do those differ from

1320

00:51:04,470 --> 00:51:02,079

the solar wind we unfortunately can't

1321

00:51:06,230 --> 00:51:04,480

get it composition but we can learn an

1322

00:51:08,390 --> 00:51:06,240

enormous amount about the interstellar

1323

00:51:10,390 --> 00:51:08,400

medium that we previously only

1324

00:51:12,470 --> 00:51:10,400

understood from looking at

1325

00:51:14,390 --> 00:51:12,480

remote using remote observations that

1326

00:51:17,190 --> 00:51:14,400

are typically integrated over many

1327

00:51:18,630 --> 00:51:17,200

parsecs so for the first time

1328

00:51:20,790 --> 00:51:18,640

we're actually going to be able to put

1329

00:51:22,549 --> 00:51:20,800

our hands into the interstellar medium

1330

00:51:23,910 --> 00:51:22,559

and look at the stuff and ask what it

1331

00:51:26,309 --> 00:51:23,920

does and what it

1332

00:51:28,549 --> 00:51:26,319

what characteristics it possesses

1333

00:51:30,309 --> 00:51:28,559

so it to my mind it may even be more

1334

00:51:33,270 --> 00:51:30,319

exciting than we've been through in the

1335

00:51:34,470 --> 00:51:33,280

past 20 years if that's possible but

1336

00:51:36,950 --> 00:51:34,480

it's going to be a trem it's a

1337

00:51:38,309 --> 00:51:36,960

tremendous opportunity

1338

00:51:39,990 --> 00:51:38,319

okay we're getting close to the top of

1339

00:51:42,150 --> 00:51:40,000

that we're going to go to social media

1340

00:51:44,069 --> 00:51:42,160

and we'll take one more and i believe

1341

00:51:45,510 --> 00:51:44,079

you have another social media event

1342

00:51:47,750 --> 00:51:45,520

happening later on this afternoon you

1343

00:51:49,349 --> 00:51:47,760

may want to share that jason

1344

00:51:51,670 --> 00:51:49,359

indeed this question comes from twitter

1345

00:51:53,589 --> 00:51:51,680

user jason major will voyager ever be

1346

00:51:57,030 --> 00:51:53,599

able to take a picture of our sun or

1347

00:51:58,069 --> 00:51:57,040

solar system from beyond the heliosphere

1348

00:51:59,829 --> 00:51:58,079

we

1349

00:52:03,030 --> 00:51:59,839

took a picture a portrait of the solar

1350

00:52:05,349 --> 00:52:03,040

system with voyager 1 in 1990 and after

1351
00:52:08,069 --> 00:52:05,359
that we unloaded the software on the

1352
00:52:09,910 --> 00:52:08,079
spacecraft to run the cameras and we no

1353
00:52:12,150 --> 00:52:09,920
longer have the computers which are

1354
00:52:14,390 --> 00:52:12,160
quite old by now on the ground to

1355
00:52:16,870 --> 00:52:14,400
process the data

1356
00:52:18,710 --> 00:52:16,880
and as we've our power supply has gotten

1357
00:52:20,390 --> 00:52:18,720
smaller and smaller we can't we would

1358
00:52:23,030 --> 00:52:20,400
not be have enough power to turn those

1359
00:52:27,829 --> 00:52:23,040
instruments back on at this point so no

1360
00:52:30,870 --> 00:52:29,109
wonderful thanks for answering a few

1361
00:52:32,790 --> 00:52:30,880
social media questions for everybody on

1362
00:52:35,030 --> 00:52:32,800
social media if you are on the platform

1363
00:52:37,109 --> 00:52:35,040

reddit later today we are going to be

1364

00:52:38,710 --> 00:52:37,119

having a bunch of our scientists uh up

1365

00:52:40,870 --> 00:52:38,720

and talking and answering questions in

1366

00:52:43,430 --> 00:52:40,880

an ama on reddit that's an ask me

1367

00:52:45,349 --> 00:52:43,440

anything so if you look on the subreddit

1368

00:52:48,150 --> 00:52:45,359

on there for an ask me anything thread

1369

00:52:50,390 --> 00:52:48,160

we'll be there later it's reddit.com

1370

00:52:52,230 --> 00:52:50,400

thank you jason so ladies and gentlemen

1371

00:52:53,829 --> 00:52:52,240

clearly we want to thank you for being

1372

00:52:55,990 --> 00:52:53,839

here before we get to the video a couple

1373

00:52:57,430 --> 00:52:56,000

of notes here again all of this

1374

00:53:00,390 --> 00:52:57,440

information and more is available on

1375

00:53:01,829 --> 00:53:00,400

www.nasa.gov

1376
00:53:04,549 --> 00:53:01,839
voyager

1377
00:53:06,870 --> 00:53:04,559
and our social media as jason said is

1378
00:53:09,990 --> 00:53:06,880
deeply abuzz on what's going on so let

1379
00:53:12,069 --> 00:53:10,000
me set up this video for you very cool

1380
00:53:13,750 --> 00:53:12,079
over the past several months

1381
00:53:16,309 --> 00:53:13,760
folks were asked what message they would

1382
00:53:17,990 --> 00:53:16,319
send to vorger to commemorate its

1383
00:53:19,510 --> 00:53:18,000
arrival and interstellar space what

1384
00:53:20,710 --> 00:53:19,520
you're going to see are some of those

1385
00:53:23,109 --> 00:53:20,720
messages

1386
00:53:25,349 --> 00:53:23,119
you know when dr grunfeld was up here

1387
00:53:28,950 --> 00:53:25,359
uh that star trek

1388
00:53:30,870 --> 00:53:28,960

context uh the the audio was low here

1389

00:53:32,470 --> 00:53:30,880

but he created quite a buzz when the

1390

00:53:34,470 --> 00:53:32,480

star trek thing was playing while he was

1391

00:53:37,030 --> 00:53:34,480

talking so check the internet for that

1392

00:53:39,349 --> 00:53:37,040

but you will recognize faces here from

1393

00:53:40,710 --> 00:53:39,359

star trek and from other places and i

1394

00:53:41,990 --> 00:53:40,720

think john

1395

00:53:43,670 --> 00:53:42,000

me being a trekkie and i think they're

1396

00:53:44,549 --> 00:53:43,680

trekkies and i know your trekkies out

1397

00:53:47,670 --> 00:53:44,559

there

1398

00:53:51,910 --> 00:53:47,680

if if mr spock was here he would say

1399

00:53:54,790 --> 00:53:53,510

thanks for joining us and enjoy the

1400

00:53:55,910 --> 00:53:54,800

video

1401

00:54:12,630 --> 00:53:55,920

thank you for joining us on this

1402

00:54:17,910 --> 00:54:15,470

there is voyager crossing over into

1403

00:54:20,150 --> 00:54:17,920

interstellar space

1404

00:54:22,870 --> 00:54:20,160

it's the farthest thing we've ever sent

1405

00:54:25,910 --> 00:54:22,880

anywhere voyager accomplished its

1406

00:54:28,309 --> 00:54:25,920

mission so brilliantly and now goes on

1407

00:54:31,990 --> 00:54:28,319

this vehicle which was which is long

1408

00:54:34,230 --> 00:54:32,000

past its expected uh service life is

1409

00:54:36,230 --> 00:54:34,240

still sending messages they're going

1410

00:54:39,270 --> 00:54:36,240

beyond what we know

1411

00:54:41,109 --> 00:54:39,280

in our neighborhood we are boldly going

1412

00:54:42,470 --> 00:54:41,119

where no one has

1413

00:54:44,470 --> 00:54:42,480

gone before

1414

00:54:47,910 --> 00:54:44,480

it's as simple as that

1415

00:54:50,470 --> 00:54:49,430

the voyager

1416

00:54:52,549 --> 00:54:50,480

record

1417

00:54:55,030 --> 00:54:52,559

and really the voyager mission were

1418

00:54:57,430 --> 00:54:55,040

conceived and executed uh on behalf of

1419

00:55:00,549 --> 00:54:57,440

all humankind with the sounds and

1420

00:55:02,950 --> 00:55:00,559

heartbeats and whale sounds and all the

1421

00:55:06,390 --> 00:55:02,960

different languages of the world

1422

00:55:07,829 --> 00:55:06,400

hello from the children of planet earth

1423

00:55:10,309 --> 00:55:07,839

my name is nick sagan i'm the son of

1424

00:55:11,829 --> 00:55:10,319

carl sagan and in the 70s i recorded

1425

00:55:13,910 --> 00:55:11,839

hello from the children of planet earth

1426

00:55:15,430 --> 00:55:13,920

for the voyager golden record

1427

00:55:17,670 --> 00:55:15,440

that would be enormously proud it would

1428

00:55:21,670 --> 00:55:17,680

be a great celebration it's an amazing

1429

00:55:24,549 --> 00:55:21,680

accomplishment pacific

1430

00:55:26,549 --> 00:55:24,559

i was selected to do portuguese it's

1431

00:55:27,829 --> 00:55:26,559

hard to imagine

1432

00:55:30,470 --> 00:55:27,839

aliens

1433

00:55:33,430 --> 00:55:30,480

being able to decipher the golden record

1434

00:55:35,750 --> 00:55:33,440

but if they can decipher it i like to

1435

00:55:38,309 --> 00:55:35,760

think that they'll they'll take our

1436

00:55:41,030 --> 00:55:38,319

message in a positive spirit

1437

00:55:43,750 --> 00:55:41,040

we stand today at the threshold of a

1438

00:55:46,309 --> 00:55:43,760

great epoch of infinite potential for

1439

00:55:48,549 --> 00:55:46,319

discovery and exploration this is not

1440

00:55:51,589 --> 00:55:48,559

science fiction this is better than

1441

00:55:53,910 --> 00:55:51,599

science fiction this is science reality

1442

00:55:57,670 --> 00:55:53,920

so voyager i bid you farewell

1443

00:55:59,270 --> 00:55:57,680

and thank you for being our ambassador

1444

00:56:00,789 --> 00:55:59,280

job well done

1445

00:56:03,190 --> 00:56:00,799

you should write

1446

00:56:04,870 --> 00:56:03,200

you should maybe drop a postcard

1447

00:56:06,950 --> 00:56:04,880

let us know how you're doing so we

1448

00:56:09,109 --> 00:56:06,960

shouldn't worry congratulations to

1449

00:56:10,390 --> 00:56:09,119

everyone on the voyager team but don't

1450

00:56:12,470 --> 00:56:10,400

stop there

1451

00:56:15,549 --> 00:56:12,480

many more worlds to explore

1452

00:56:18,230 --> 00:56:15,559

and thank you for expanding

1453

00:56:32,870 --> 00:56:18,240

humankind's universe