



AVI LOEB

“The New Frontier
of Interstellar Objects”



1
00:00:02,180 --> 00:00:37,229

[Music]

2
00:00:42,830 --> 00:00:40,350

thank you so much Gary and I truly hope

3
00:00:46,110 --> 00:00:42,840

that we have a partner out there in

4
00:00:48,750 --> 00:00:46,120

interstellar space because we all know

5
00:00:51,590 --> 00:00:48,760

what Steven Weinberg the Nobel laureate

6
00:00:55,069 --> 00:00:51,600

said at the end of his book the first

7
00:00:57,869 --> 00:00:55,079

three minutes he said that the most the

8
00:01:00,910 --> 00:00:57,879

more we understand the universe the more

9
00:01:02,709 --> 00:01:00,920

pointless it looks

10
00:01:04,829 --> 00:01:02,719

and of course I understand that because

11
00:01:09,469 --> 00:01:04,839

Steven Weinberg and most cosmologist

12
00:01:11,550 --> 00:01:09,479

focus on lifeless entities Elementary

13
00:01:14,630 --> 00:01:11,560

particles

14

00:01:17,550 --> 00:01:14,640

stars and we know from our private life

15

00:01:19,310 --> 00:01:17,560

that finding a partner provides a

16

00:01:22,830 --> 00:01:19,320

meaning to our

17

00:01:26,469 --> 00:01:22,840

existence the same holds for finding a

18

00:01:28,830 --> 00:01:26,479

partner in OU space suddenly the

19

00:01:33,990 --> 00:01:28,840

universe will not appear to be

20

00:01:44,789 --> 00:01:37,990

and um what I'll discuss today um can be

21

00:01:49,870 --> 00:01:47,270

Interstellar there is a new frontier in

22

00:01:52,830 --> 00:01:49,880

astronomy that's what brought me to this

23

00:01:55,310 --> 00:01:52,840

discussion um when Gary mentioned the

24

00:01:58,230 --> 00:01:55,320

table I was actually traumatized at the

25

00:02:00,749 --> 00:01:58,240

dinner table as a young kid because I

26

00:02:02,469 --> 00:02:00,759

would ask a difficult question

27

00:02:06,270 --> 00:02:02,479

and the adults in the

28

00:02:08,389 --> 00:02:06,280

room would dismiss it because they

29

00:02:11,830 --> 00:02:08,399

wouldn't know the answer and they didn't

30

00:02:14,589 --> 00:02:11,840

want to show any weakness so they just

31

00:02:18,430 --> 00:02:14,599

removed the question off the table that

32

00:02:21,550 --> 00:02:18,440

was traumatizing to me as a kid and I

33

00:02:26,229 --> 00:02:21,560

haven't changed since then I'm still a

34

00:02:28,550 --> 00:02:26,239

curious kid that grew up on a farm and

35

00:02:31,190 --> 00:02:28,560

um I decided to become a scientist so I

36

00:02:33,710 --> 00:02:31,200

can answer the question Myself by

37

00:02:35,670 --> 00:02:33,720

collecting evidence that's a great

38

00:02:38,309 --> 00:02:35,680

privilege you don't need to rely on

39

00:02:39,309 --> 00:02:38,319

other people forget about people just

40

00:02:44,390 --> 00:02:39,319

look at

41

00:02:48,149 --> 00:02:44,400

nature so over the past decade we found

42

00:02:51,350 --> 00:02:48,159

the first objects from outside the solar

43

00:02:53,390 --> 00:02:51,360

system and the experience is like

44

00:02:55,589 --> 00:02:53,400

watching objects that come from the

45

00:02:58,030 --> 00:02:55,599

street into your

46

00:03:00,830 --> 00:02:58,040

backyard of course many of them might be

47

00:03:03,710 --> 00:03:00,840

rocks like the ones that we are familiar

48

00:03:06,589 --> 00:03:03,720

with but there might also be a tennis

49

00:03:11,710 --> 00:03:06,599

ball that was thrown by a

50

00:03:14,750 --> 00:03:11,720

neighbor so for me the interest in this

51
00:03:17,910 --> 00:03:14,760
was maybe we can find a technological

52
00:03:20,430 --> 00:03:17,920
needle in this haast stack of rocks that

53
00:03:22,350 --> 00:03:20,440
are familiar to us and what I find is

54
00:03:25,110 --> 00:03:22,360
that my colleagues in Academia keep

55
00:03:28,670 --> 00:03:25,120
saying everything in the sky must be

56
00:03:31,869 --> 00:03:28,680
Stones I call that the Stone Age of

57
00:03:39,030 --> 00:03:35,429
so the first three Interstellar objects

58
00:03:41,070 --> 00:03:39,040
were the following on January 8

59
00:03:43,750 --> 00:03:41,080
2014 a

60
00:03:46,229 --> 00:03:43,760
meteor collided with Earth it was the

61
00:03:49,470 --> 00:03:46,239
size of a watermelon a meteor is an

62
00:03:51,750 --> 00:03:49,480
object that burns up in the atmosphere

63
00:03:55,830 --> 00:03:51,760

as a result of its friction with

64

00:03:58,429 --> 00:03:55,840

air this one was anomalous it was

65

00:04:00,390 --> 00:03:58,439

detected by US Government satellites and

66

00:04:02,589 --> 00:04:00,400

was moving very fast

67

00:04:06,789 --> 00:04:02,599

in fact it came from behind the Earth as

68

00:04:10,229 --> 00:04:06,799

it orbits the Sun and even though it was

69

00:04:12,789 --> 00:04:10,239

trailing us it moved already at 40 km/

70

00:04:14,110 --> 00:04:12,799

second relative to Earth and so all

71

00:04:16,590 --> 00:04:14,120

together we

72

00:04:20,229 --> 00:04:16,600

calculated outside the solar system it

73

00:04:22,909 --> 00:04:20,239

was moving at 60 km/ second that's a

74

00:04:26,469 --> 00:04:22,919

thousand times more than the speed limit

75

00:04:29,350 --> 00:04:26,479

on a highway and it's faster than

76

00:04:30,230 --> 00:04:29,360

95% of the stars in the vicinity of the

77

00:04:32,870 --> 00:04:30,240

Sun

78

00:04:35,590 --> 00:04:32,880

so that was anomalous and yet in

79

00:04:37,469 --> 00:04:35,600

addition to that it was able to maintain

80

00:04:40,950 --> 00:04:37,479

its Integrity all the way down to the

81

00:04:43,830 --> 00:04:40,960

low atmosphere uh where the stress on it

82

00:04:47,189 --> 00:04:43,840

was far greater than on any other meteor

83

00:04:50,350 --> 00:04:47,199

that NASA catalog 272 of them over the

84

00:04:52,350 --> 00:04:50,360

past decade so I thought well that's

85

00:04:54,790 --> 00:04:52,360

interesting it could be a voyager like

86

00:04:57,430 --> 00:04:54,800

meteor imagine our own spacecraft

87

00:05:00,510 --> 00:04:57,440

colliding with another planet like Earth

88

00:05:03,909 --> 00:05:00,520

in the future and burning up in its

89

00:05:06,310 --> 00:05:03,919

atmosphere it would that meteor that

90

00:05:08,230 --> 00:05:06,320

would be visible there would be of

91

00:05:11,189 --> 00:05:08,240

unusual material strength because it's

92

00:05:13,870 --> 00:05:11,199

made of an artificial alloy and would

93

00:05:16,510 --> 00:05:13,880

also move at an unusual speed because it

94

00:05:19,510 --> 00:05:16,520

benefited from chemical

95

00:05:22,029 --> 00:05:19,520

propulsion and then almost four years

96

00:05:24,990 --> 00:05:22,039

later a telescope in Hawaii named pan

97

00:05:26,629 --> 00:05:25,000

stars discovered a much bigger object

98

00:05:29,029 --> 00:05:26,639

that didn't collide with Earth it was

99

00:05:31,749 --> 00:05:29,039

the size of a football field was given

100

00:05:33,110 --> 00:05:31,759

the name om mua mua which means a scout

101

00:05:36,350 --> 00:05:33,120

in the Hawaiian

102

00:05:38,629 --> 00:05:36,360

language and the amount of sunlight

103

00:05:42,189 --> 00:05:38,639

reflected from it changed by a factor of

104

00:05:44,390 --> 00:05:42,199

10 as it was tumbling every eight hours

105

00:05:47,950 --> 00:05:44,400

and the most likely shape of the object

106

00:05:49,710 --> 00:05:47,960

was that of a pancake a flat object very

107

00:05:52,830 --> 00:05:49,720

unusual unlike the rocks that we are

108

00:05:56,230 --> 00:05:52,840

familiar with it also exhibited some

109

00:05:58,909 --> 00:05:56,240

non-gravitational push away from the Sun

110

00:06:02,870 --> 00:05:58,919

without showing any cometary evaporation

111

00:06:06,629 --> 00:06:02,880

there was no trail of dust or gas around

112

00:06:08,790 --> 00:06:06,639

it and so I found that intriguing unlike

113

00:06:11,990 --> 00:06:08,800

the rocks that we are familiar

114

00:06:14,550 --> 00:06:12,000

with and my colleagues were saying No

115

00:06:16,950 --> 00:06:14,560

it's it's a rock it's a rock of a type

116

00:06:19,909 --> 00:06:16,960

that we've never seen before a hydrogen

117

00:06:22,550 --> 00:06:19,919

Iceberg a nitrogen Iceberg a Dust

118

00:06:25,150 --> 00:06:22,560

Bunny the version changed every few

119

00:06:27,189 --> 00:06:25,160

months but it was always natural and

120

00:06:32,430 --> 00:06:27,199

they always said how dare you even bring

121

00:06:37,749 --> 00:06:35,309

origin and by the way that's exactly

122

00:06:40,150 --> 00:06:37,759

what a cave dweller would say when

123

00:06:42,510 --> 00:06:40,160

finding a cell phone it's a rock of a

124

00:06:47,029 --> 00:06:42,520

type that we've never seen

125

00:06:49,990 --> 00:06:47,039

before um on August 29th 2019 finally

126
00:06:52,110 --> 00:06:50,000
the third object showed up it was

127
00:06:54,870 --> 00:06:52,120
discovered by an amateur astronomer

128
00:06:57,869 --> 00:06:54,880
Gennady borisov and that one was a

129
00:07:00,150 --> 00:06:57,879
familiar Comet didn't look any different

130
00:07:02,589 --> 00:07:00,160
than the Comets that we we saw many

131
00:07:06,070 --> 00:07:02,599
times in the solar

132
00:07:09,070 --> 00:07:06,080
system so here is an interesting case

133
00:07:12,390 --> 00:07:09,080
out of three objects that came from

134
00:07:15,950 --> 00:07:12,400
Interstellar space the first two were

135
00:07:18,309 --> 00:07:15,960
unlike the rocks in the solar system so

136
00:07:20,430 --> 00:07:18,319
could they be technologically in origin

137
00:07:22,830 --> 00:07:20,440
this is just a question I'm just asking

138
00:07:25,350 --> 00:07:22,840

a question at the dinner

139

00:07:26,869 --> 00:07:25,360

table why are the adults in the room

140

00:07:30,029 --> 00:07:26,879

dismissing

141

00:07:34,029 --> 00:07:30,039

it now what is an Interstellar

142

00:07:36,909 --> 00:07:34,039

object just imagine the sun here in red

143

00:07:39,430 --> 00:07:36,919

uh the Earth is orbiting in a circle

144

00:07:42,550 --> 00:07:39,440

around the Sun at 30

145

00:07:46,070 --> 00:07:42,560

km/s if the Earth was moving slightly

146

00:07:47,909 --> 00:07:46,080

faster at 42 km/ second it would escape

147

00:07:51,670 --> 00:07:47,919

the gravitational pool of the sun it

148

00:07:54,430 --> 00:07:51,680

would run out of the solar system so any

149

00:07:56,589 --> 00:07:54,440

object at that distance moving faster

150

00:07:59,710 --> 00:07:56,599

than 42

151
00:08:01,710 --> 00:07:59,720
km/s would be considered Interstellar

152
00:08:03,990 --> 00:08:01,720
because it cannot be bound to the sun it

153
00:08:05,830 --> 00:08:04,000
can be part of the solar system that's

154
00:08:08,110 --> 00:08:05,840
the definition of an Interstellar object

155
00:08:11,589 --> 00:08:08,120
that that's how you find

156
00:08:14,390 --> 00:08:11,599
it and UA mua was

157
00:08:17,110 --> 00:08:14,400
one and here are two Alternatives that

158
00:08:19,990 --> 00:08:17,120
were put out in the literature one is a

159
00:08:24,790 --> 00:08:20,000
very unusual rock made of hydrogen

160
00:08:26,670 --> 00:08:24,800
nitrogen dust you name it or maybe a

161
00:08:29,589 --> 00:08:26,680
very thin object that was pushed by

162
00:08:32,550 --> 00:08:29,599
reflecting sunlight as I suggested and

163
00:08:35,670 --> 00:08:32,560

that could be a surface layer of a

164

00:08:38,909 --> 00:08:35,680

bigger object or a broken piece for

165

00:08:45,150 --> 00:08:43,230

Sphere now uh playwright in Los Angeles

166

00:08:47,190 --> 00:08:45,160

was inspired by this work that I did on

167

00:08:49,910 --> 00:08:47,200

om mua mua he wrote a play that was

168

00:08:52,310 --> 00:08:49,920

presented at my home a couple of months

169

00:08:54,590 --> 00:08:52,320

ago and I just wanted to mention two

170

00:08:58,949 --> 00:08:54,600

statements from that

171

00:09:03,430 --> 00:08:58,959

play the first relates to social media

172

00:09:04,829 --> 00:09:03,440

and to Academia I should add why is

173

00:09:13,590 --> 00:09:04,839

childlike

174

00:09:16,990 --> 00:09:13,600

curiosity that really bothers me why are

175

00:09:18,870 --> 00:09:17,000

people more attracted to

176

00:09:21,670 --> 00:09:18,880

destructive

177

00:09:23,269 --> 00:09:21,680

interactions than to constructive ones

178

00:09:26,269 --> 00:09:23,279

after all we can all work together to

179

00:09:29,990 --> 00:09:26,279

figure it out what's the big

180

00:09:32,829 --> 00:09:30,000

deal and the second uh item that I

181

00:09:36,310 --> 00:09:32,839

wanted to bring up is that I often Tell

182

00:09:38,949 --> 00:09:36,320

Young scientists never pretend to be the

183

00:09:41,910 --> 00:09:38,959

adults in the room and I say that to all

184

00:09:44,389 --> 00:09:41,920

of you even though all of you are

185

00:09:46,509 --> 00:09:44,399

adults what I mean is

186

00:09:48,110 --> 00:09:46,519

metaphorically you should maintain your

187

00:09:50,829 --> 00:09:48,120

childhood

188

00:09:53,069 --> 00:09:50,839

curiosity because that's the only way to

189

00:09:55,430 --> 00:09:53,079

discover new

190

00:09:57,069 --> 00:09:55,440

knowledge and so what I'll describe is

191

00:09:59,670 --> 00:09:57,079

work done over the past two and a half

192

00:10:01,389 --> 00:09:59,680

years by the Galileo project team

193

00:10:04,829 --> 00:10:01,399

uh three of its members are in the

194

00:10:08,150 --> 00:10:04,839

audience and I challenge you to find

195

00:10:12,790 --> 00:10:08,160

them from this

196

00:10:15,310 --> 00:10:12,800

picture and what we developed um is a an

197

00:10:17,310 --> 00:10:15,320

observatory that is currently collecting

198

00:10:19,590 --> 00:10:17,320

data at Harvard

199

00:10:21,350 --> 00:10:19,600

University uh and I'll show you a brief

200

00:10:25,389 --> 00:10:21,360

video that summarizes the various

201
00:10:29,389 --> 00:10:25,399
instruments we basically taking a video

202
00:10:31,829 --> 00:10:29,399
with audio a movie of the sky at all

203
00:10:33,230 --> 00:10:31,839
times at one location and we are

204
00:10:35,389 --> 00:10:33,240
planning to make copies of that

205
00:10:38,350 --> 00:10:35,399
Observatory and put them in many other

206
00:10:41,350 --> 00:10:38,360
locations throughout the US to figure

207
00:10:50,030 --> 00:10:41,360
out whether there are objects that came

208
00:10:54,670 --> 00:10:52,790
us welcome to an overview of the Galileo

209
00:10:56,949 --> 00:10:54,680
projects development site codeen named

210
00:10:58,790 --> 00:10:56,959
pigeon run our instrumentation Suite

211
00:11:00,910 --> 00:10:58,800
consists of both wide field and narrow

212
00:11:02,550 --> 00:11:00,920
field field sensors wide field sensors

213
00:11:04,470 --> 00:11:02,560

are used for Target selection and

214

00:11:06,069 --> 00:11:04,480

tracking while narrow field sensors

215

00:11:07,910 --> 00:11:06,079

gather higher resolution data on

216

00:11:11,629 --> 00:11:07,920

potentially anomalous

217

00:11:13,829 --> 00:11:11,639

objects our main instrument is diic a

218

00:11:16,870 --> 00:11:13,839

hemispherical array of eight infrared

219

00:11:19,670 --> 00:11:16,880

cameras next to it is the Alor a

220

00:11:21,590 --> 00:11:19,680

secondary highresolution Optical all Sky

221

00:11:23,350 --> 00:11:21,600

camera together these instruments

222

00:11:25,430 --> 00:11:23,360

continuously Monitor and track objects

223

00:11:28,190 --> 00:11:25,440

in the sky analyzing them in real time

224

00:11:30,230 --> 00:11:28,200

for potential anomalous activity this is

225

00:11:31,949 --> 00:11:30,240

Amos our acoustic monitoring

226

00:11:33,910 --> 00:11:31,959

omnidirectional system designed to

227

00:11:35,829 --> 00:11:33,920

detect and record acoustic signatures

228

00:11:38,870 --> 00:11:35,839

across the infrasonic audible and

229

00:11:40,949 --> 00:11:38,880

ultrasonic bands Amos also houses an

230

00:11:43,430 --> 00:11:40,959

adsb antenna for logging aircraft

231

00:11:46,350 --> 00:11:43,440

transponder data allowing us to quickly

232

00:11:48,710 --> 00:11:46,360

separate known from unknown

233

00:11:50,750 --> 00:11:48,720

objects here we have Skywatch a

234

00:11:52,470 --> 00:11:50,760

multistatic passive radar system

235

00:11:54,590 --> 00:11:52,480

designed to detect and track multiple

236

00:11:56,990 --> 00:11:54,600

objects simultaneously measuring object

237

00:11:59,790 --> 00:11:57,000

positions and

238

00:12:01,550 --> 00:11:59,800

kinematics n Pacman is an environmental

239

00:12:04,069 --> 00:12:01,560

monitoring system for measuring local

240

00:12:06,750 --> 00:12:04,079

weather conditions sensors include an

241

00:12:09,910 --> 00:12:06,760

anomet temperature and pressure sensors

242

00:12:12,230 --> 00:12:09,920

a particle counter and a flux gate

243

00:12:14,069 --> 00:12:12,240

magnetometer next up is Spectre a radio

244

00:12:15,629 --> 00:12:14,079

spectrum analyzer with a wide band

245

00:12:17,150 --> 00:12:15,639

antenna for measuring radio and

246

00:12:19,470 --> 00:12:17,160

microwave

247

00:12:21,590 --> 00:12:19,480

emissions Beacon is currently our only

248

00:12:23,829 --> 00:12:21,600

narrow field instrument Beacon is a

249

00:12:26,990 --> 00:12:23,839

highresolution pan tilt zoom camera

250

00:12:29,030 --> 00:12:27,000

capable of 40 times optical zoom our

251
00:12:30,670 --> 00:12:29,040
instruments collect a wide range of data

252
00:12:33,110 --> 00:12:30,680
all of which is fed to our Computing

253
00:12:36,230 --> 00:12:33,120
enclosure housed beneath the dalic and

254
00:12:38,590 --> 00:12:36,240
Alor instruments here data is processed

255
00:12:40,350 --> 00:12:38,600
and analyzed in real time objects

256
00:12:43,110 --> 00:12:40,360
detected and tracked by the Widefield

257
00:12:46,350 --> 00:12:43,120
instruments are localized in 3D space

258
00:12:48,150 --> 00:12:46,360
and analyzed for unusual characteristics

259
00:12:51,230 --> 00:12:48,160
selected targets are then sent to the

260
00:12:53,470 --> 00:12:51,240
beacon PTZ for follow-up

261
00:12:56,790 --> 00:12:53,480
observation finally data is recorded to

262
00:12:59,430 --> 00:12:56,800
disk and uploaded to the cloud via

263
00:13:01,310 --> 00:12:59,440

starlink these combined systems comprise

264

00:13:03,629 --> 00:13:01,320

the current version of The Observatory

265

00:13:05,590 --> 00:13:03,639

class system with many refinements

266

00:13:08,870 --> 00:13:05,600

additions and upgrades scheduled for

267

00:13:11,389 --> 00:13:08,880

near-term implementation at pigeon

268

00:13:13,670 --> 00:13:11,399

run so we know how to do it we are

269

00:13:17,310 --> 00:13:13,680

getting data as we

270

00:13:19,710 --> 00:13:17,320

speak uh for over a month now we're

271

00:13:22,870 --> 00:13:19,720

analyzing it with machine learning

272

00:13:25,590 --> 00:13:22,880

algorithms we want it to be automated so

273

00:13:27,590 --> 00:13:25,600

the human factor is not biasing any

274

00:13:29,509 --> 00:13:27,600

conclusion that we reach and we are

275

00:13:32,509 --> 00:13:29,519

trying to figure out if in addition to

276

00:13:34,750 --> 00:13:32,519

birds balloons drones airplanes things

277

00:13:36,430 --> 00:13:34,760

that are familiar there is something

278

00:13:41,949 --> 00:13:36,440

unfamiliar out

279

00:13:44,310 --> 00:13:41,959

there and um obviously we will um use

280

00:13:46,550 --> 00:13:44,320

different data sets to figure out what

281

00:13:49,430 --> 00:13:46,560

these things are uh the scientific way

282

00:13:51,430 --> 00:13:49,440

and report about it openly to the public

283

00:13:54,069 --> 00:13:51,440

our work is complementary to that of

284

00:13:55,670 --> 00:13:54,079

government the day job of government is

285

00:13:59,350 --> 00:13:55,680

National

286

00:14:02,389 --> 00:13:59,360

Security frankly anything that says made

287

00:14:05,790 --> 00:14:02,399

in China is boring as far as I'm

288

00:14:10,470 --> 00:14:05,800

concerned I want to see if it says Made

289

00:14:13,949 --> 00:14:10,480

in an exoplanet far

290

00:14:16,110 --> 00:14:13,959

away and we are using satellite data

291

00:14:19,990 --> 00:14:16,120

looking at objects from above not just

292

00:14:22,269 --> 00:14:20,000

from below using planet lab's um

293

00:14:26,509 --> 00:14:22,279

satellite

294

00:14:29,949 --> 00:14:26,519

imagery and we have um a plan as to how

295

00:14:31,710 --> 00:14:29,959

to expand the current system that we

296

00:14:34,230 --> 00:14:31,720

have operating it costs about half a

297

00:14:37,749 --> 00:14:34,240

million dollars and we're happy to make

298

00:14:40,110 --> 00:14:37,759

more copies uh it just depends on the

299

00:14:41,829 --> 00:14:40,120

funding that we have so if there's any

300

00:14:43,790 --> 00:14:41,839

potential donor in the audience that

301
00:14:46,910 --> 00:14:43,800
would like to have an observatory named

302
00:14:49,269 --> 00:14:46,920
after them uh please reach out to me we

303
00:14:52,990 --> 00:14:49,279
know exactly what to do we can build it

304
00:14:57,470 --> 00:14:53,000
in a place uh of your

305
00:15:00,110 --> 00:14:57,480
liking and we published eight papers by

306
00:15:04,509 --> 00:15:00,120
now but but what I want to focus on

307
00:15:06,110 --> 00:15:04,519
today is um the interstellar meteor that

308
00:15:09,350 --> 00:15:06,120
I mentioned at the beginning that was

309
00:15:13,949 --> 00:15:09,360
really the first Interstellar object

310
00:15:16,509 --> 00:15:13,959
discovered uh by humans uh and um I

311
00:15:18,949 --> 00:15:16,519
decided to lead an expedition to the

312
00:15:22,670 --> 00:15:18,959
Pacific Ocean this summer between June

313
00:15:24,590 --> 00:15:22,680

14th to 28th two weeks in the ocean

314

00:15:27,870 --> 00:15:24,600

searching for the materials of this

315

00:15:30,550 --> 00:15:27,880

object and I wrote 43 diary reports

316

00:15:33,269 --> 00:15:30,560

during that Expedition they were read by

317

00:15:35,670 --> 00:15:33,279

millions around the world translated to

318

00:15:39,189 --> 00:15:35,680

Spanish a lot of people thanked me for

319

00:15:41,910 --> 00:15:39,199

showing how science should be

320

00:15:46,030 --> 00:15:41,920

done and so this object was discovered

321

00:15:49,110 --> 00:15:46,040

in 2014 but it took 5 years before I

322

00:15:54,350 --> 00:15:49,120

decided to look into it with my student

323

00:15:56,990 --> 00:15:54,360

Amir SJ um and we were searching the

324

00:15:59,430 --> 00:15:57,000

catalog of meteors that NASA put

325

00:16:02,230 --> 00:15:59,440

publicly and looking for for objects

326

00:16:04,309 --> 00:16:02,240

that are potentially Interstellar moving

327

00:16:06,309 --> 00:16:04,319

very fast and we identified this one we

328

00:16:09,790 --> 00:16:06,319

wrote a paper submitted it for

329

00:16:11,590 --> 00:16:09,800

publication and the reviewer said no

330

00:16:13,189 --> 00:16:11,600

this should not be published we don't

331

00:16:17,030 --> 00:16:13,199

believe the US

332

00:16:20,629 --> 00:16:17,040

government and so it took three years

333

00:16:22,550 --> 00:16:20,639

for me to reach out to colleagues within

334

00:16:25,350 --> 00:16:22,560

government through the White House

335

00:16:27,949 --> 00:16:25,360

getting to the US space

336

00:16:30,110 --> 00:16:27,959

command uh for the US space command to

337

00:16:33,150 --> 00:16:30,120

issue a formal letter to

338

00:16:36,269 --> 00:16:33,160

NASA uh stating that they looked into

339

00:16:39,069 --> 00:16:36,279

the data and can confirm at the

340

00:16:42,430 --> 00:16:39,079

99.999% confidence that indeed this

341

00:16:45,150 --> 00:16:42,440

object came from Interstellar space at

342

00:16:47,110 --> 00:16:45,160

which point our paper was accepted for

343

00:16:49,309 --> 00:16:47,120

publication and the government also

344

00:16:51,990 --> 00:16:49,319

released the light curve of the fireball

345

00:16:54,470 --> 00:16:52,000

that was generated this event produced

346

00:16:55,749 --> 00:16:54,480

about a few per of the Hiroshima atomic

347

00:16:59,309 --> 00:16:55,759

bomb

348

00:17:01,710 --> 00:16:59,319

energy and um based on the data we

349

00:17:03,430 --> 00:17:01,720

concluded that the object was at least

350

00:17:06,309 --> 00:17:03,440

the size of a watermelon it could have

351

00:17:08,230 --> 00:17:06,319

been bigger than that the three flares

352

00:17:11,630 --> 00:17:08,240

that were seen from this Fireball were

353

00:17:14,270 --> 00:17:11,640

separated by a tenth of a second and uh

354

00:17:19,549 --> 00:17:14,280

from the fact that they occurred um

355

00:17:21,990 --> 00:17:19,559

within 20 kilm above the ocean surface

356

00:17:25,029 --> 00:17:22,000

we were able to tell that the material

357

00:17:28,549 --> 00:17:25,039

strength of this object was tougher than

358

00:17:29,590 --> 00:17:28,559

iron it was tougher than all space rocks

359

00:17:33,470 --> 00:17:29,600

that NASA

360

00:17:38,909 --> 00:17:36,110

before and at that point I decided to

361

00:17:41,390 --> 00:17:38,919

lead an expedition because I'm a

362

00:17:42,950 --> 00:17:41,400

theoretical physicist but nobody else

363

00:17:46,630 --> 00:17:42,960

would do it

364

00:17:50,669 --> 00:17:46,640

unless I I bring together the the team

365

00:17:52,590 --> 00:17:50,679

and uh so um we used the error box of

366

00:17:55,669 --> 00:17:52,600

the Department of Defense which was 7

367

00:17:58,590 --> 00:17:55,679

miles on a side and we wanted to

368

00:18:01,310 --> 00:17:58,600

localize the meteor path better and we

369

00:18:05,110 --> 00:18:01,320

found some public data from a sesom on

370

00:18:08,149 --> 00:18:05,120

Manus Island in Papua nugini and just as

371

00:18:11,310 --> 00:18:08,159

in the case of a thunder where where you

372

00:18:12,350 --> 00:18:11,320

hear the sound after you see the light

373

00:18:16,630 --> 00:18:12,360

from the

374

00:18:19,830 --> 00:18:16,640

lightning uh we detected a sound signal

375

00:18:21,990 --> 00:18:19,840

on this s moment data and from the time

376

00:18:25,070 --> 00:18:22,000

delay we could tell the distance of the

377

00:18:27,270 --> 00:18:25,080

explosion knowing the speed of sound and

378

00:18:30,710 --> 00:18:27,280

that led us to the red strip that you

379

00:18:34,350 --> 00:18:30,720

see Within the dod error

380

00:18:36,669 --> 00:18:34,360

box so we rented the ship that was

381

00:18:40,110 --> 00:18:36,679

fittingly called Silver

382

00:18:43,029 --> 00:18:40,120

Star uh from Australia and I'll show you

383

00:18:44,590 --> 00:18:43,039

some photographs from that

384

00:18:48,870 --> 00:18:44,600

expedition

385

00:18:52,710 --> 00:18:48,880

drifting in my

386

00:18:55,669 --> 00:18:52,720

S thinking I

387

00:18:57,310 --> 00:18:55,679

am where you

388

00:18:59,470 --> 00:18:57,320

are

389

00:19:01,630 --> 00:18:59,480

drifting

390

00:19:05,430 --> 00:19:01,640

my

391

00:19:08,470 --> 00:19:05,440

Sil thinking I am

392

00:19:10,029 --> 00:19:08,480

one where you

393

00:19:14,310 --> 00:19:10,039

are

394

00:19:18,149 --> 00:19:14,320

drifting in my

395

00:19:21,110 --> 00:19:18,159

sister thinking I am

396

00:19:22,830 --> 00:19:21,120

one where you

397

00:19:28,750 --> 00:19:22,840

are

398

00:19:30,950 --> 00:19:28,760

drifting in my Sil Stone think

399

00:19:35,950 --> 00:19:30,960

I am

400

00:19:43,110 --> 00:19:39,710

are so here is the deck of the ship with

401
00:19:44,990 --> 00:19:43,120
the 28 people that came on board some of

402
00:19:47,630 --> 00:19:45,000
the best engineers and

403
00:19:50,789 --> 00:19:47,640
Navigators in the world I was very

404
00:19:54,510 --> 00:19:50,799
pleased that they chose to join us and

405
00:19:57,350 --> 00:19:54,520
what you see behind the team is an

406
00:19:59,110 --> 00:19:57,360
A-frame that was directing a cable

407
00:20:02,750 --> 00:19:59,120
connected to the ship

408
00:20:06,029 --> 00:20:02,760
to a sled that we put down on the ocean

409
00:20:10,190 --> 00:20:06,039
floor with magnets on both sides to

410
00:20:12,630 --> 00:20:10,200
collect particles that were melted off

411
00:20:15,190 --> 00:20:12,640
the surface of the object when it was

412
00:20:17,710 --> 00:20:15,200
exposed to the immense heat from the

413
00:20:18,630 --> 00:20:17,720

fireball that it generated as a result

414

00:20:21,510 --> 00:20:18,640

of its

415

00:20:24,470 --> 00:20:21,520

friction and so we were looking for

416

00:20:28,909 --> 00:20:24,480

millimet sized particles the size of a

417

00:20:31,909 --> 00:20:28,919

grain of sand at a mile deep ocean

418

00:20:34,270 --> 00:20:31,919

across a region of seven miles that

419

00:20:37,549 --> 00:20:34,280

sounds hopeless and indeed many people

420

00:20:41,950 --> 00:20:37,559

said why waste the

421

00:20:44,909 --> 00:20:41,960

time but very often in life it's

422

00:20:48,830 --> 00:20:44,919

important to be an optimist because

423

00:20:51,630 --> 00:20:48,840

sometimes life is a self-fulfilling

424

00:20:53,270 --> 00:20:51,640

prophecy so here are some more images

425

00:20:57,549 --> 00:20:53,280

what you see in the middle and the right

426
00:21:00,630 --> 00:20:57,559
hand side are images of us pulling the

427
00:21:04,630 --> 00:21:00,640
sled up out of the water um the cable

428
00:21:08,029 --> 00:21:04,640
was about 3 Mi long so it took about an

429
00:21:12,070 --> 00:21:08,039
hour to bring the sled up and then we

430
00:21:13,750 --> 00:21:12,080
would put it flat on the deck and scrape

431
00:21:15,830 --> 00:21:13,760
the magnets for all the magnetic

432
00:21:18,190 --> 00:21:15,840
particles that we found what you see on

433
00:21:21,750 --> 00:21:18,200
the bottom left and middle is me jogging

434
00:21:24,630 --> 00:21:21,760
at Sunrise as I do on land I kept this

435
00:21:27,590 --> 00:21:24,640
routine on the ship and we had a filming

436
00:21:29,149 --> 00:21:27,600
crew there one out of 50 that wanted to

437
00:21:31,750 --> 00:21:29,159
join us

438
00:21:34,390 --> 00:21:31,760

uh and they asked me if they can film me

439

00:21:36,590 --> 00:21:34,400

jogging in the morning so they asked me

440

00:21:39,750 --> 00:21:36,600

could you please jog a little more and

441

00:21:43,510 --> 00:21:39,760

it ended up being nine

442

00:21:45,510 --> 00:21:43,520

miles uh and I realized that my workout

443

00:21:48,430 --> 00:21:45,520

app is actually not measuring my speed

444

00:21:50,590 --> 00:21:48,440

it measures the speed of the ship just

445

00:21:55,909 --> 00:21:50,600

keep that in mind if you are ever

446

00:21:58,870 --> 00:21:55,919

jogging on a ship um it's GPS uh and at

447

00:22:02,190 --> 00:21:58,880

the end of my run uh the director of

448

00:22:04,149 --> 00:22:02,200

this documentary asked me AI it looks

449

00:22:06,870 --> 00:22:04,159

like you're running are you running away

450

00:22:10,190 --> 00:22:06,880

from something or towards something and

451
00:22:12,350 --> 00:22:10,200
I replied both I'm running away from

452
00:22:15,830 --> 00:22:12,360
some of my colleagues who have very

453
00:22:17,669 --> 00:22:15,840
strong opinions without seeking evidence

454
00:22:21,750 --> 00:22:17,679
and I'm running towards a higher

455
00:22:24,390 --> 00:22:21,760
intelligence in interstellar

456
00:22:27,750 --> 00:22:24,400
space so here are some more photos you

457
00:22:29,950 --> 00:22:27,760
can see the sled um uh and we use the

458
00:22:32,269 --> 00:22:29,960
VAC vacuum cleaner sometimes to clean it

459
00:22:35,070 --> 00:22:32,279
up from all the magnetic particles and

460
00:22:38,549 --> 00:22:35,080
then we would dry up uh whatever was in

461
00:22:41,149 --> 00:22:38,559
the vacuum cleaner uh and we would put

462
00:22:44,710 --> 00:22:41,159
those particles under a microscope that

463
00:22:48,710 --> 00:22:44,720

we had on the ship uh but in the first

464

00:22:51,870 --> 00:22:48,720

six days all we found was volcanic ash

465

00:22:55,909 --> 00:22:51,880

black powder tiny particles from

466

00:22:58,830 --> 00:22:55,919

Earth and I was

467

00:23:01,909 --> 00:22:58,840

frustrated uh and then uh at that point

468

00:23:06,269 --> 00:23:01,919

we decided to filter the material and

469

00:23:09,110 --> 00:23:06,279

let the volcanic ash go um using a mesh

470

00:23:11,390 --> 00:23:09,120

size of about a quarter of a millimeter

471

00:23:14,710 --> 00:23:11,400

and the bigger particles were put under

472

00:23:18,669 --> 00:23:14,720

a microscope and lo and behold we found

473

00:23:21,750 --> 00:23:18,679

a molten droplet from a meteor and I

474

00:23:23,149 --> 00:23:21,760

knew it I I was thrilled I I hugged the

475

00:23:25,990 --> 00:23:23,159

person who saw it first on the

476

00:23:29,430 --> 00:23:26,000

microscope because I knew that uh when I

477

00:23:32,149 --> 00:23:29,440

find an ant in the kitchen I get alarmed

478

00:23:34,750 --> 00:23:32,159

there must be many more ants out there

479

00:23:36,350 --> 00:23:34,760

and indeed we found 50 of those ferals

480

00:23:40,669 --> 00:23:36,360

on the

481

00:23:45,029 --> 00:23:40,679

ship so let me show you a brief video of

482

00:23:48,350 --> 00:23:45,039

um how the image from down below how the

483

00:23:50,590 --> 00:23:48,360

sled was going over the ocean floor it

484

00:23:54,230 --> 00:23:50,600

it was basically like mowing the lawn

485

00:23:58,149 --> 00:23:54,240

except there was no lawn down there at a

486

00:24:02,510 --> 00:23:58,159

mile deep there was we saw some shrimp

487

00:24:05,230 --> 00:24:02,520

um but it was mostly mck uh and the the

488

00:24:08,950 --> 00:24:05,240

magnets on the sled were collecting uh

489

00:24:11,590 --> 00:24:08,960

magnetic particles that we brought up uh

490

00:24:15,590 --> 00:24:11,600

and every now and then we would um

491

00:24:17,669 --> 00:24:15,600

encounter a rock that um would slow us

492

00:24:19,590 --> 00:24:17,679

down a bit the biggest challenge was to

493

00:24:22,350 --> 00:24:19,600

keep the sled on the ocean floor because

494

00:24:24,789 --> 00:24:22,360

it was kiting as a result of the tension

495

00:24:27,549 --> 00:24:24,799

in the cable it was floating above the

496

00:24:29,830 --> 00:24:27,559

surface so that required some expertise

497

00:24:31,870 --> 00:24:29,840

here you see a rock obviously we

498

00:24:35,230 --> 00:24:31,880

couldn't collect this one but we are

499

00:24:38,230 --> 00:24:35,240

hoping to go back and look for bigger

500

00:24:39,590 --> 00:24:38,240

pieces of the original meteor because

501
00:24:42,870 --> 00:24:39,600
that could tell us the difference

502
00:24:45,470 --> 00:24:42,880
between a rock a natural object and an

503
00:24:47,510 --> 00:24:45,480
artificial Gadget and I asked my

504
00:24:49,789 --> 00:24:47,520
students at class if we find a gadget

505
00:24:50,549 --> 00:24:49,799
and it has buttons on it should we press

506
00:25:51,230 --> 00:24:50,559
a

507
00:25:53,830 --> 00:25:51,240
hopeful

508
00:25:56,990 --> 00:25:53,840
but uh Paula

509
00:25:59,750 --> 00:25:57,000
Antonelli summarized her vision with

510
00:26:06,070 --> 00:26:03,149
she said love the

511
00:26:08,269 --> 00:26:06,080
aliens and what she meant is that we

512
00:26:11,909 --> 00:26:08,279
should love each

513
00:26:15,830 --> 00:26:11,919

other especially when we are different

514

00:26:18,510 --> 00:26:15,840

frankly I am INF fluctuated

515

00:26:22,149 --> 00:26:18,520

by others that might be smarter than I

516

00:26:27,070 --> 00:26:24,710

them so I promised Paula that I will

517

00:26:30,510 --> 00:26:27,080

bring if we find anything in the next

518

00:26:32,190 --> 00:26:30,520

Expedition and I'll bring it for exhibit

519

00:26:34,230 --> 00:26:32,200

at the Museum of Modern Art because it

520

00:26:38,590 --> 00:26:34,240

would represent modernity for us even

521

00:26:45,149 --> 00:26:42,029

senders at an event we went 26 times

522

00:26:48,029 --> 00:26:45,159

across this error box and in some

523

00:26:51,990 --> 00:26:48,039

control regions to figure out the

524

00:26:54,149 --> 00:26:52,000

background and um here you on the left

525

00:26:56,669 --> 00:26:54,159

you can see the Whiteboard where we

526

00:26:59,630 --> 00:26:56,679

wrote the number of 50 we thought that's

527

00:27:03,070 --> 00:26:59,640

amazing we found 50 ferrets molten

528

00:27:04,110 --> 00:27:03,080

droplets but uh we shipped the entirety

529

00:27:08,590 --> 00:27:04,120

of the

530

00:27:10,590 --> 00:27:08,600

materials um with FedEx to my home but

531

00:27:13,269 --> 00:27:10,600

um here you see an image from the

532

00:27:15,389 --> 00:27:13,279

microscope that demonstrates how

533

00:27:16,630 --> 00:27:15,399

distinct are these spherules they look

534

00:27:19,230 --> 00:27:16,640

like metallic

535

00:27:23,389 --> 00:27:19,240

marbles uh relative to the background

536

00:27:26,710 --> 00:27:23,399

sand and we pick them with tweezers and

537

00:27:29,590 --> 00:27:26,720

when I posted these images on medium uh

538

00:27:32,190 --> 00:27:29,600

my daughter saw them and said uh could

539

00:27:35,590 --> 00:27:32,200

you please uh thread one of them on a

540

00:27:37,389 --> 00:27:35,600

necklace for me and I said uh well they

541

00:27:39,669 --> 00:27:37,399

are millimeter in size and they're made

542

00:27:41,710 --> 00:27:39,679

mostly of iron it's not practical she

543

00:27:43,990 --> 00:27:41,720

was very

544

00:27:46,110 --> 00:27:44,000

disappointed uh and so we delivered

545

00:27:49,430 --> 00:27:46,120

those babies uh what you see is the

546

00:27:51,950 --> 00:27:49,440

delivery room which uh looks like a

547

00:27:55,669 --> 00:27:51,960

white container white

548

00:27:58,430 --> 00:27:55,679

box uh and we put the babies instead of

549

00:28:00,710 --> 00:27:58,440

in their beds we put them in in vials

550

00:28:07,230 --> 00:28:00,720

and we marked we labeled those

551
00:28:10,149 --> 00:28:07,240
vials uh 50 speros Shi them to my home

552
00:28:13,470 --> 00:28:10,159
and you can see on the right hand side

553
00:28:15,149 --> 00:28:13,480
the uh suitcase that they were in and

554
00:28:17,110 --> 00:28:15,159
when I received it and opened it I

555
00:28:18,950 --> 00:28:17,120
realized well FedEx took a few extra

556
00:28:20,509 --> 00:28:18,960
days to deliver it but it's nothing

557
00:28:24,509 --> 00:28:20,519
compared to the billions of years that

558
00:28:26,710 --> 00:28:24,519
he took the material to arrive here so

559
00:28:30,430 --> 00:28:26,720
it's not a big delay and what you see on

560
00:28:33,630 --> 00:28:30,440
the left is is the team examining the

561
00:28:36,990 --> 00:28:33,640
sled on a rainy night the funer is

562
00:28:38,669 --> 00:28:37,000
actually to my right in a black raincoat

563
00:28:41,190 --> 00:28:38,679

Charles

564

00:28:43,789 --> 00:28:41,200

hoskinson and so I brought the materials

565

00:28:47,070 --> 00:28:43,799

to my colleague at Harvard Stein

566

00:28:49,710 --> 00:28:47,080

Jacobson who has a one of the best mass

567

00:28:52,549 --> 00:28:49,720

spectrometers in the world you see it in

568

00:28:56,029 --> 00:28:52,559

front of us uh

569

00:28:58,870 --> 00:28:56,039

and uh on the other side of me in this

570

00:29:02,110 --> 00:28:58,880

photo you can see my summer intern

571

00:29:05,269 --> 00:29:02,120

Sophie Bergstrom who decided to Shadow

572

00:29:07,029 --> 00:29:05,279

me this summer and um write about how I

573

00:29:10,269 --> 00:29:07,039

do my science because she wants to

574

00:29:12,630 --> 00:29:10,279

become a science journalist but at some

575

00:29:14,710 --> 00:29:12,640

point she said um could I help you with

576

00:29:17,190 --> 00:29:14,720

a science and I said sure and I gave her

577

00:29:18,830 --> 00:29:17,200

a pair of twizzles and the microscope

578

00:29:20,509 --> 00:29:18,840

she went through the materials again and

579

00:29:24,269 --> 00:29:20,519

found 600

580

00:29:25,909 --> 00:29:24,279

spheral so I gave her the honorary title

581

00:29:29,430 --> 00:29:25,919

The spheral

582

00:29:33,430 --> 00:29:29,440

Hunter and we have many more now so alt

583

00:29:37,029 --> 00:29:33,440

together nearly 800 spheros out of which

584

00:29:41,950 --> 00:29:37,039

we analyzed only 57 publicly and we are

585

00:29:45,269 --> 00:29:41,960

currently these days analyze the um

586

00:29:48,990 --> 00:29:45,279

we're analyzing 93% of the sample that

587

00:29:53,230 --> 00:29:49,000

we have so most of it is not yet uh

588

00:29:56,509 --> 00:29:53,240

analyzed but when we made a map of the

589

00:29:59,190 --> 00:29:56,519

distribution of spherical um this is a map

590

00:30:02,230 --> 00:29:59,200

of the yield of ferals per amount of

591

00:30:04,110 --> 00:30:02,240

mass that was retrieved and this map was

592

00:30:06,470 --> 00:30:04,120

produced by Laura dummin who is in the

593

00:30:08,870 --> 00:30:06,480

audience here a member of the Galileo

594

00:30:12,149 --> 00:30:08,880

project uh what we found is that near

595

00:30:15,470 --> 00:30:12,159

the meteor path which is delineated in

596

00:30:18,990 --> 00:30:15,480

Orange um I mean the left side is the

597

00:30:22,029 --> 00:30:19,000

zoomed out map and the right side is the

598

00:30:24,750 --> 00:30:22,039

zoomed in map of the meteor path uh what

599

00:30:27,350 --> 00:30:24,760

we found is that there are enhancements

600

00:30:30,830 --> 00:30:27,360

in the yield in in these yellow regions

601
00:30:33,789 --> 00:30:30,840
close to the meteor path relative to the

602
00:30:35,590 --> 00:30:33,799
background and so it means that we were

603
00:30:38,710 --> 00:30:35,600
in the right

604
00:30:40,669 --> 00:30:38,720
spot and U on the first day as we came

605
00:30:43,029 --> 00:30:40,679
back from the Expedition we passed

606
00:30:45,990 --> 00:30:43,039
through San Francisco Airport went to

607
00:30:48,549 --> 00:30:46,000
Burkley and used a scanning electron

608
00:30:50,590 --> 00:30:48,559
microscope to look at the inside of some

609
00:30:52,990 --> 00:30:50,600
of the spheral and what we found is

610
00:30:56,149 --> 00:30:53,000
amazing there are spheres inside spheres

611
00:30:59,389 --> 00:30:56,159
just like Russian dolls and the idea is

612
00:31:02,430 --> 00:30:59,399
that uh the small spheres solidified

613
00:31:06,789 --> 00:31:02,440

first and then they were engulfed with

614

00:31:09,029 --> 00:31:06,799

molten iron that glued them

615

00:31:10,950 --> 00:31:09,039

together here is a sphere that looks

616

00:31:13,470 --> 00:31:10,960

like a soccer

617

00:31:16,110 --> 00:31:13,480

ball and another one that looks like a

618

00:31:18,950 --> 00:31:16,120

merger of three

619

00:31:20,870 --> 00:31:18,960

spheres and this one was particularly

620

00:31:23,990 --> 00:31:20,880

interesting because it was in a yellow

621

00:31:29,029 --> 00:31:24,000

region it was one of the biggest that we

622

00:31:30,470 --> 00:31:29,039

had 1.3 mm in the diameter so we decided

623

00:31:34,190 --> 00:31:30,480

to analyze it

624

00:31:36,710 --> 00:31:34,200

first and what we found is that the iron

625

00:31:41,230 --> 00:31:36,720

Isotopes have a ratio that is very

626
00:31:42,070 --> 00:31:41,240
different from rocks on Earth or Mars or

627
00:31:44,990 --> 00:31:42,080
the

628
00:31:47,789 --> 00:31:45,000
moon but most importantly we looked at

629
00:31:50,669 --> 00:31:47,799
the concentration of elements in the

630
00:31:54,230 --> 00:31:50,679
periodic table starting from lithium on

631
00:31:57,269 --> 00:31:54,240
the left going to Uranium on the right

632
00:31:59,830 --> 00:31:57,279
and we normalize the abundances relative

633
00:32:02,470 --> 00:31:59,840
to the standard solar composition so

634
00:32:06,070 --> 00:32:02,480
that's the composition of the stuff that

635
00:32:09,470 --> 00:32:06,080
made the solar system that's marked by

636
00:32:13,629 --> 00:32:09,480
one on this plot and what we found is

637
00:32:17,710 --> 00:32:13,639
that elements like berum lanthanum and

638
00:32:20,509 --> 00:32:17,720

uranium have a higher abundance by

639

00:32:22,110 --> 00:32:20,519

factors of hundreds to a thousand

640

00:32:24,310 --> 00:32:22,120

relative to the standard solar

641

00:32:26,110 --> 00:32:24,320

composition and it's not just these

642

00:32:30,990 --> 00:32:26,120

three elements you can see many in

643

00:32:33,830 --> 00:32:31,000

between uh and um we decided since this

644

00:32:35,710 --> 00:32:33,840

abundance pattern was never seen never

645

00:32:37,669 --> 00:32:35,720

reported in the literature the

646

00:32:40,669 --> 00:32:37,679

scientific literature we had to give it

647

00:32:44,190 --> 00:32:40,679

a new name which

648

00:32:45,750 --> 00:32:44,200

we um decided would be below for berum

649

00:32:48,350 --> 00:32:45,760

lanum and

650

00:32:49,830 --> 00:32:48,360

uranium that's a new type of speros

651
00:32:52,350 --> 00:32:49,840
never seen

652
00:32:54,950 --> 00:32:52,360
before and here are five of them that

653
00:32:57,110 --> 00:32:54,960
have this Bellow composition and here we

654
00:32:59,830 --> 00:32:57,120
plot the elements based on their vola

655
00:33:02,470 --> 00:32:59,840
ility meaning that elements on the right

656
00:33:05,470 --> 00:33:02,480
can be easily lost as a result of

657
00:33:09,830 --> 00:33:05,480
evaporation during an explosion during

658
00:33:12,389 --> 00:33:09,840
an air burst and indeed they are missing

659
00:33:15,669 --> 00:33:12,399
those elements have a lower

660
00:33:19,430 --> 00:33:15,679
abundance uh than expected and so that

661
00:33:22,269 --> 00:33:19,440
demonstrates that the Bellow ferals were

662
00:33:25,710 --> 00:33:22,279
associated with an

663
00:33:33,710 --> 00:33:29,629

meteor now now in recent days this week

664

00:33:36,110 --> 00:33:33,720

you must have heard those bloggers and

665

00:33:39,230 --> 00:33:36,120

scientists astronomers or people that

666

00:33:42,549 --> 00:33:39,240

call themselves astrophysicist they're

667

00:33:48,310 --> 00:33:42,559

not real scientists um who say that what

668

00:33:54,549 --> 00:33:52,509

Ash and that's a bit strange I was asked

669

00:33:56,549 --> 00:33:54,559

by a reporter this morning I said look

670

00:33:58,470 --> 00:33:56,559

we were using a magnetic sled with

671

00:34:03,110 --> 00:33:58,480

magnets

672

00:34:10,349 --> 00:34:07,310

iron so you know if you are smart you

673

00:34:13,230 --> 00:34:10,359

choose the battles that you fight that

674

00:34:15,589 --> 00:34:13,240

you are willing to die on but apparently

675

00:34:18,349 --> 00:34:15,599

these people were willing to die on a on

676
00:34:21,310 --> 00:34:18,359
a bottle that makes no sense whatsoever I

677
00:34:23,909 --> 00:34:21,320
just don't understand why they are doing

678
00:34:27,510 --> 00:34:23,919
it and in fact we you can see here a

679
00:34:30,270 --> 00:34:27,520
plot that shows at one corner the iron

680
00:34:34,869 --> 00:34:30,280
abundance another silicon at the third

681
00:34:38,950 --> 00:34:34,879
one magnesium and the Bellow ferals are

682
00:34:40,750 --> 00:34:38,960
located very far away from fly ash which

683
00:34:45,550 --> 00:34:40,760
is in the

684
00:34:46,589 --> 00:34:45,560
upper corner so no way that we could

685
00:34:50,550 --> 00:34:46,599
have

686
00:34:54,310 --> 00:34:50,560
confused fly ash with the Bellow

687
00:34:57,069 --> 00:34:54,320
ferals and you know it's really strange

688
00:34:58,829 --> 00:34:57,079

that there is there are those people who

689

00:35:00,950 --> 00:34:58,839

jump up and down and I'm not talking

690

00:35:03,790 --> 00:35:00,960

about one or two I'm talking about a lot

691

00:35:07,150 --> 00:35:03,800

of people cheering up to what they

692

00:35:09,109 --> 00:35:07,160

said uh saying the problem is solved

693

00:35:12,990 --> 00:35:09,119

this Expedition

694

00:35:14,630 --> 00:35:13,000

found our own

695

00:35:18,190 --> 00:35:14,640

coal

696

00:35:21,670 --> 00:35:18,200

um it's to me very sad to see that

697

00:35:24,710 --> 00:35:21,680

because it shows how this information can

698

00:35:28,470 --> 00:35:24,720

propagate even on matters of Science and

699

00:35:32,030 --> 00:35:28,480

one of these bloggers when I

700

00:35:34,430 --> 00:35:32,040

said that he calls himself an

701

00:35:36,310 --> 00:35:34,440

astrophysicist but he never he didn't

702

00:35:39,670 --> 00:35:36,320

publish a single scientific paper over

703

00:35:43,349 --> 00:35:39,680

the past decade so how dare he talk

704

00:35:45,510 --> 00:35:43,359

about it I mean as if he is a practicing

705

00:35:48,470 --> 00:35:45,520

scientist uh he's a

706

00:35:50,990 --> 00:35:48,480

pretender how can he represent the way

707

00:35:53,109 --> 00:35:51,000

science is done how can he tell

708

00:35:55,710 --> 00:35:53,119

practicing scientists what to do it's

709

00:35:58,309 --> 00:35:55,720

like commentators telling soccer players

710

00:36:02,270 --> 00:35:58,319

how to pass the ball

711

00:36:05,190 --> 00:36:02,280

um and he saw this and put it on his

712

00:36:09,270 --> 00:36:05,200

Twitter handle the

713

00:36:11,670 --> 00:36:09,280

title a blogger who did not publish for

714

00:36:14,109 --> 00:36:11,680

a decade so he is proud of his

715

00:36:17,510 --> 00:36:14,119

incompetence and my point is really

716

00:36:20,030 --> 00:36:17,520

simple my point is simple those who are

717

00:36:22,710 --> 00:36:20,040

proud of their

718

00:36:26,790 --> 00:36:22,720

incompetence will not

719

00:36:28,510 --> 00:36:26,800

terrorize real scientists I don't give a

720

00:36:30,990 --> 00:36:28,520

damn about what he

721

00:36:37,390 --> 00:36:31,000

says it's all about paying attention to

722

00:36:43,790 --> 00:36:39,910

data so then the question is where did

723

00:36:47,870 --> 00:36:43,800

this Bellow composition originate from

724

00:36:51,470 --> 00:36:47,880

and I have two alternative scenarios one

725

00:36:54,589 --> 00:36:51,480

is a natural explanation and uh one can

726

00:36:56,710 --> 00:36:54,599

explain it imagining a planet outside

727

00:37:00,150 --> 00:36:56,720

the solar system because this was not

728

00:37:03,550 --> 00:37:00,160

not found on Earth Mars the moon

729

00:37:08,230 --> 00:37:03,560

asteroids so imagine an exoplanet that

730

00:37:11,150 --> 00:37:08,240

had a magma ocean and an iron core some

731

00:37:14,190 --> 00:37:11,160

elements would sink to the center of the

732

00:37:16,390 --> 00:37:14,200

planet and others will be left behind in

733

00:37:20,430 --> 00:37:16,400

the crust those are the elements that we

734

00:37:23,990 --> 00:37:20,440

see enhanced so if there is a planet an

735

00:37:25,589 --> 00:37:24,000

exop planet that was a magma ocean and

736

00:37:29,030 --> 00:37:25,599

was ripped

737

00:37:31,190 --> 00:37:29,040

apart then perhaps this meteor came from

738

00:37:34,790 --> 00:37:31,200

it and in

739

00:37:37,109 --> 00:37:34,800

fact if you take the Earth we all know

740

00:37:39,510 --> 00:37:37,119

about the tide that the moon raises in

741

00:37:41,309 --> 00:37:39,520

the ocean so just imagine replacing the

742

00:37:44,150 --> 00:37:41,319

moon with the

743

00:37:47,270 --> 00:37:44,160

sun even if you put the Earth next to

744

00:37:50,390 --> 00:37:47,280

the sun it will not be disrupted by the

745

00:37:52,430 --> 00:37:50,400

tidal force of the sun because the

746

00:37:53,670 --> 00:37:52,440

density of the sun is less than the

747

00:37:56,790 --> 00:37:53,680

density of

748

00:37:59,910 --> 00:37:56,800

rock but if you consider the most

749

00:38:01,829 --> 00:37:59,920

abundant type of stars dwarf stars the

750

00:38:05,109 --> 00:38:01,839

nearest one is Proxima centari the

751
00:38:07,349 --> 00:38:05,119
nearest star 12% of the mass of the Sun

752
00:38:09,910 --> 00:38:07,359
about a tenth of the radius of the sun

753
00:38:12,309 --> 00:38:09,920
such stars are a 100 times denser than

754
00:38:15,030 --> 00:38:12,319
Rock so if you take a planet like the

755
00:38:16,309 --> 00:38:15,040
Earth and bring it close to such a star

756
00:38:18,990 --> 00:38:16,319
it would get

757
00:38:21,430 --> 00:38:19,000
spaghettified elongated into a stream of

758
00:38:23,990 --> 00:38:21,440
rocks half of which will be ejected to

759
00:38:27,230 --> 00:38:24,000
Interstellar space at a speed that we

760
00:38:29,510 --> 00:38:27,240
calculated is similar to this meteor

761
00:38:32,630 --> 00:38:29,520
so here is a natur possible natural

762
00:38:35,030 --> 00:38:32,640
origin but of course it's also possible

763
00:38:37,950 --> 00:38:35,040

that it was artificial in

764

00:38:41,430 --> 00:38:37,960

origin and I want to emphasize that this

765

00:38:44,990 --> 00:38:41,440

expedition was risky it was not obvious

766

00:38:47,510 --> 00:38:45,000

that we'll get funded at1 and A5

767

00:38:50,150 --> 00:38:47,520

million uh I might not have been

768

00:38:53,109 --> 00:38:50,160

successful at recruiting qualified

769

00:38:54,870 --> 00:38:53,119

engineers and Navigators for this task

770

00:38:58,589 --> 00:38:54,880

our Machinery might not have

771

00:39:01,109 --> 00:38:58,599

accomplished the task perhaps the the

772

00:39:03,309 --> 00:39:01,119

sled would not sit on the ocean floor so

773

00:39:06,150 --> 00:39:03,319

we would never collect anything and this

774

00:39:09,190 --> 00:39:06,160

meteor might have not had enough Mass to

775

00:39:11,430 --> 00:39:09,200

provide us with enough spheral for us to

776

00:39:13,910 --> 00:39:11,440

find and moreover my colleague at

777

00:39:17,069 --> 00:39:13,920

Harvard might have told me that he's too

778

00:39:21,030 --> 00:39:17,079

busy uh and he cannot help me and then

779

00:39:25,950 --> 00:39:23,670

composition so what I'm trying to say is

780

00:39:27,790 --> 00:39:25,960

to in order to find new knowledge we

781

00:39:30,150 --> 00:39:27,800

really need to take

782

00:39:32,710 --> 00:39:30,160

risks and our goal in the next

783

00:39:36,109 --> 00:39:32,720

Expedition is potentially to visit that

784

00:39:38,550 --> 00:39:36,119

site again and look for bigger pieces

785

00:39:41,670 --> 00:39:38,560

and here I am standing next to Art

786

00:39:44,190 --> 00:39:41,680

Wright the party chief of this

787

00:39:47,230 --> 00:39:44,200

Expedition who was the commander of a

788

00:39:49,990 --> 00:39:47,240

destroyer during the Vietnam war he's 85

789

00:39:52,270 --> 00:39:50,000

years old I really liked him because he

790

00:39:53,390 --> 00:39:52,280

didn't say much but everything he said

791

00:39:55,990 --> 00:39:53,400

was

792

00:39:58,630 --> 00:39:56,000

right and we were looking at the sunset

793

00:40:01,349 --> 00:39:58,640

on the last last day and planning the

794

00:40:05,190 --> 00:40:04,430

Expedition so in summary I just wanted

795

00:40:07,990 --> 00:40:05,200

to

796

00:40:12,270 --> 00:40:08,000

mention the guiding principles that I

797

00:40:19,430 --> 00:40:15,589

experience first of all most important

798

00:40:21,230 --> 00:40:19,440

is to follow evidence by collecting data

799

00:40:24,190 --> 00:40:21,240

with state-ofthe-art

800

00:40:26,470 --> 00:40:24,200

instruments that are fully under control

801
00:40:28,790 --> 00:40:26,480
and are well calibrated in other words

802
00:40:30,829 --> 00:40:28,800
instruments that you

803
00:40:34,430 --> 00:40:30,839
understand that's the way science is

804
00:40:39,510 --> 00:40:34,440
done not by polling how many people like

805
00:40:44,390 --> 00:40:42,349
X and I'm I'm sure that Elon Musk is not

806
00:40:45,750 --> 00:40:44,400
putting such a poll because I'm not sure

807
00:40:47,550 --> 00:40:45,760
how he

808
00:40:49,470 --> 00:40:47,560
will be

809
00:40:53,430 --> 00:40:49,480
ranked

810
00:40:56,309 --> 00:40:53,440
um and then the

811
00:40:58,309 --> 00:40:56,319
principle that FIFA the football

812
00:41:01,190 --> 00:40:58,319
Association

813
00:41:02,829 --> 00:41:01,200

Advocates listen to eyewitnesses that's

814

00:41:06,190 --> 00:41:02,839

perfectly fine you know if a player

815

00:41:09,430 --> 00:41:06,200

comes along and says I thought that the

816

00:41:12,790 --> 00:41:09,440

ball really went past the the goal you

817

00:41:14,750 --> 00:41:12,800

know uh you can listen to that and you

818

00:41:17,270 --> 00:41:14,760

what but what you do to decide what

819

00:41:18,910 --> 00:41:17,280

really happened is to go to the cameras

820

00:41:21,309 --> 00:41:18,920

and

821

00:41:23,950 --> 00:41:21,319

check that's what FIFA

822

00:41:26,030 --> 00:41:23,960

does they don't decide based on what the

823

00:41:27,309 --> 00:41:26,040

players tell them or the audience tells

824

00:41:28,870 --> 00:41:27,319

them

825

00:41:31,390 --> 00:41:28,880

because we all know that when there is a

826

00:41:34,349 --> 00:41:31,400

car accident different people give very

827

00:41:36,670 --> 00:41:34,359

different reports about what

828

00:41:40,390 --> 00:41:36,680

happened so science is done by

829

00:41:45,630 --> 00:41:40,400

instruments to avoid a bias

830

00:41:51,309 --> 00:41:48,309

have and then another principle from

831

00:41:54,829 --> 00:41:51,319

sports that is advocated by basketball

832

00:41:57,150 --> 00:41:54,839

coaches keep your eyes on the ball not

833

00:42:01,109 --> 00:41:57,160

on the audience I'm looking at the

834

00:42:04,950 --> 00:42:01,119

audience but I should um and what I mean

835

00:42:06,589 --> 00:42:04,960

by that is that I have no footprint on

836

00:42:09,190 --> 00:42:06,599

social

837

00:42:15,069 --> 00:42:09,200

media I don't care how many likes I get

838

00:42:20,349 --> 00:42:16,589

irrelevant

839

00:42:24,630 --> 00:42:20,359
because if you listen to too many

840

00:42:30,790 --> 00:42:24,640
people you basically reduce yourself to

841

00:42:36,829 --> 00:42:32,309
and another

842

00:42:39,710 --> 00:42:36,839
important phenomenon that I um obviously

843

00:42:42,270 --> 00:42:39,720
witnessed is those Pretenders who

844

00:42:44,390 --> 00:42:42,280
pretend to protect science they say that

845

00:42:47,750 --> 00:42:44,400
they are pro

846

00:42:49,349 --> 00:42:47,760
science but they ignore facts that

847

00:42:51,829 --> 00:42:49,359
disagree with their

848

00:42:53,750 --> 00:42:51,839
models and so for example two

849

00:42:55,510 --> 00:42:53,760
astronomers on the day that I came back

850

00:42:57,950 --> 00:42:55,520
from the Expedition published the paper

851
00:43:01,309 --> 00:42:57,960
in the astrophysical IAL Journal saying

852
00:43:03,270 --> 00:43:01,319
that the government measured the speed

853
00:43:05,630 --> 00:43:03,280
incorrectly it was three times smaller

854
00:43:08,309 --> 00:43:05,640
this object was actually a stone from

855
00:43:10,230 --> 00:43:08,319
the solar system they did it at the time

856
00:43:17,230 --> 00:43:10,240
that I was bringing back the

857
00:43:24,150 --> 00:43:21,270
wait another important uh principle

858
00:43:25,069 --> 00:43:24,160
don't mud wrestle because those who call

859
00:43:32,190 --> 00:43:25,079
you

860
00:43:35,430 --> 00:43:32,200
so just ignore

861
00:43:38,270 --> 00:43:35,440
it and Rise instead to the greatest

862
00:43:41,309 --> 00:43:38,280
Heights of scientific practice where the

863
00:43:44,950 --> 00:43:41,319

oxygen level is too low for these

864

00:43:48,829 --> 00:43:44,960

critics My Hope Is that they will drop

865

00:43:50,309 --> 00:43:48,839

off just like crows that drop off the

866

00:43:53,710 --> 00:43:50,319

back of an

867

00:43:56,510 --> 00:43:53,720

eagle and stop pecking at its neck I

868

00:43:59,030 --> 00:43:56,520

should say they haven't stopped yet I'm

869

00:44:02,270 --> 00:43:59,040

doing my best to get rid of

870

00:44:04,230 --> 00:44:02,280

them and as I mentioned before it's

871

00:44:06,829 --> 00:44:04,240

important to be an optimist because life

872

00:44:09,710 --> 00:44:06,839

is a self-fulfilling prophecy and