

1
00:00:10,109 --> 00:00:19,929
thank you very much dr. Stross Meier I

2
00:00:14,820 --> 00:00:22,269
been very pleased and honored and happy

3
00:00:19,929 --> 00:00:24,570
to get to experience the very warm

4
00:00:22,269 --> 00:00:27,730
welcome I have received here in Potsdam

5
00:00:24,570 --> 00:00:32,500
is a great pleasure to be here with you

6
00:00:27,730 --> 00:00:34,750
at the Leiden it's colleague and also at

7
00:00:32,500 --> 00:00:37,480
the Astra observatory

8
00:00:34,750 --> 00:00:41,230
astronomic Astrophysical Institute at

9
00:00:37,479 --> 00:00:42,359
Potsdam it's been a wonderful trip for

10
00:00:41,229 --> 00:00:45,789
me so far

11
00:00:42,359 --> 00:00:47,560
you're very fine people and I'm a happy

12
00:00:45,789 --> 00:00:52,329
person thank you for the very fine

13
00:00:47,560 --> 00:00:54,880
birthday gift I am here to talk to you

14
00:00:52,329 --> 00:00:57,699
about the particularly the search for

15
00:00:54,880 --> 00:01:00,310
extraterrestrial life and we must keep

16
00:00:57,700 --> 00:01:02,109
in mind two things there's primitive

17
00:01:00,310 --> 00:01:04,329
life which was probably much more

18
00:01:02,109 --> 00:01:06,519
abundant in the universe and there's

19
00:01:04,328 --> 00:01:08,500
intelligent life which is probably not

20
00:01:06,519 --> 00:01:10,658
as abundant but yet it's probably more

21
00:01:08,500 --> 00:01:13,409
interesting because that is what most

22
00:01:10,659 --> 00:01:16,570
people are particularly interested in

23
00:01:13,409 --> 00:01:18,880
and I'm going to show you how the

24
00:01:16,569 --> 00:01:21,219
probabilities of the existence of life

25
00:01:18,879 --> 00:01:23,199
and the ways in which we search for it

26
00:01:21,219 --> 00:01:25,569
depend very much on astrophysics and

27
00:01:23,200 --> 00:01:30,430
physics in general which is why the

28
00:01:25,569 --> 00:01:33,669
title of my talk is as it is now I want

29

00:01:30,430 --> 00:01:37,780
to start out by talking about where we

30
00:01:33,670 --> 00:01:40,329
might find life how common might it be

31
00:01:37,780 --> 00:01:42,579
in the universe because this gives us

32
00:01:40,329 --> 00:01:45,429
guidance as to how difficult our search

33
00:01:42,579 --> 00:01:49,030
may be and what procedures will work

34
00:01:45,430 --> 00:01:51,670
best to find that life to start off with

35
00:01:49,030 --> 00:01:53,618
what do we mean by life when we talk

36
00:01:51,670 --> 00:01:56,650
about life at present we have to talk

37
00:01:53,618 --> 00:01:58,810
about life as we know it the life of

38
00:01:56,650 --> 00:02:02,580
Earth the way it works it's chemistry

39
00:01:58,810 --> 00:02:06,909
its history of evolution these things

40
00:02:02,579 --> 00:02:09,519
which we know we wish we knew the same

41
00:02:06,909 --> 00:02:11,800
sort of information for other forms of

42
00:02:09,519 --> 00:02:14,439
life in the universe but we don't

43
00:02:11,800 --> 00:02:16,200

and so much of what we do in thinking

44

00:02:14,439 --> 00:02:20,530

about extraterrestrial life is based on

45

00:02:16,199 --> 00:02:22,449

life as we know it life on Earth and so

46

00:02:20,530 --> 00:02:24,120

when we think about searching for life

47

00:02:22,449 --> 00:02:27,099

in space we sort of think about

48

00:02:24,120 --> 00:02:30,849

searching for other Earth's like the

49

00:02:27,099 --> 00:02:33,609

nice image you see here well what is

50

00:02:30,849 --> 00:02:36,370

life as we know it it's basically very

51

00:02:33,610 --> 00:02:38,340

simple it's organic compounds

52

00:02:36,370 --> 00:02:42,180

carbon-based compounds interacting

53

00:02:38,340 --> 00:02:45,030

primarily in a solvent known as water

54

00:02:42,180 --> 00:02:48,969

fortunately a solvent which is very

55

00:02:45,030 --> 00:02:51,819

common on our planet so what it takes to

56

00:02:48,969 --> 00:02:55,300

make life is water organic compounds and

57

00:02:51,819 --> 00:02:58,120

one other thing which is energy you know

58
00:02:55,300 --> 00:03:00,160
and here on earth all of the energy of

59
00:02:58,120 --> 00:03:03,550
life comes primarily at least to begin

60
00:03:00,159 --> 00:03:05,650
with from our Sun and of course it's

61
00:03:03,550 --> 00:03:08,140
converted by plants into food and things

62
00:03:05,650 --> 00:03:12,610
like that but basically the source of

63
00:03:08,139 --> 00:03:14,889
energy is the Sun and so when we look

64
00:03:12,610 --> 00:03:17,380
out into space and consider where else

65
00:03:14,889 --> 00:03:22,929
there might be life we always have in

66
00:03:17,379 --> 00:03:25,000
mind perhaps and too limited away that

67
00:03:22,930 --> 00:03:30,370
what we're really searching for is

68
00:03:25,000 --> 00:03:34,709
places with water energy and organic

69
00:03:30,370 --> 00:03:34,709
compounds now

70
00:03:35,479 --> 00:03:40,219
when we say water we mean liquid water

71
00:03:37,729 --> 00:03:43,009
we don't know a ways of making life and

72
00:03:40,219 --> 00:03:46,810
spin solid water that is ice or in the

73
00:03:43,009 --> 00:03:50,090
gaseous phase and so we look for places

74
00:03:46,810 --> 00:03:53,870
in the cosmos where the temperatures are

75
00:03:50,090 --> 00:03:57,590
right for liquid water to exist and this

76
00:03:53,870 --> 00:04:01,280
has led to the concepts you see here

77
00:03:57,590 --> 00:04:05,989
which is that around each star there is

78
00:04:01,280 --> 00:04:08,989
a thick shell as you see here within

79
00:04:05,989 --> 00:04:11,739
which bodies will have on the surface a

80
00:04:08,989 --> 00:04:14,269
temperature suitable for liquid water

81
00:04:11,739 --> 00:04:17,090
now you see here three different kinds

82
00:04:14,269 --> 00:04:20,298
of stars in the astronomers rather

83
00:04:17,089 --> 00:04:23,119
awkward nomenclature and f-type stars a

84
00:04:20,298 --> 00:04:26,120
very massive bright star a jeep type

85
00:04:23,120 --> 00:04:29,600
star is a medium-sized star in fact our

86

00:04:26,120 --> 00:04:31,840
Sun is one of those but in fact most of

87
00:04:29,600 --> 00:04:34,850
the stars in our galaxy the Milky Way

88
00:04:31,839 --> 00:04:38,060
are a third type of star called the

89
00:04:34,850 --> 00:04:40,820
eminent type star which is a very faint

90
00:04:38,060 --> 00:04:44,538
star this brightness is only a few

91
00:04:40,819 --> 00:04:47,060
percent at best that of the Sun now what

92
00:04:44,538 --> 00:04:49,038
comes of this is that when the star is

93
00:04:47,060 --> 00:04:51,228
very bright of course you can have

94
00:04:49,038 --> 00:04:53,870
temperatures high enough to support

95
00:04:51,228 --> 00:04:56,149
liquid water far from the star and those

96
00:04:53,870 --> 00:04:57,410
temperatures will continue until you're

97
00:04:56,149 --> 00:04:59,089
so far from the star that the

98
00:04:57,410 --> 00:05:01,420
temperatures fall to the freezing point

99
00:04:59,089 --> 00:05:03,549
of water and so that

100
00:05:01,420 --> 00:05:06,550

is how we determine the zone which

101

00:05:03,550 --> 00:05:09,790

within which habitable planets might

102

00:05:06,550 --> 00:05:11,770

exist for a star like our Sun somewhat

103

00:05:09,790 --> 00:05:15,760

finger the habitable zone is more narrow

104

00:05:11,769 --> 00:05:19,479

and for the other type star it's this

105

00:05:15,759 --> 00:05:21,909

little tiny donut you see here now

106

00:05:19,480 --> 00:05:23,560

historically astronomers have looked at

107

00:05:21,910 --> 00:05:26,260

the picture just like this and they've

108

00:05:23,560 --> 00:05:29,079

said all right about the only place we

109

00:05:26,259 --> 00:05:31,810

might find life in the universe is

110

00:05:29,079 --> 00:05:35,529

around the g-type stars and the f-type

111

00:05:31,810 --> 00:05:37,089

stars but the M stars are very faint the

112

00:05:35,529 --> 00:05:39,250

potential zone of 1/2 middle

113

00:05:37,089 --> 00:05:41,889

habitability is very small and it seems

114

00:05:39,250 --> 00:05:46,750

unlikely that there would be planets in

115
00:05:41,889 --> 00:05:49,000
that zone well that's a concept as it

116
00:05:46,750 --> 00:05:49,750
was many of the concepts with regard to

117
00:05:49,000 --> 00:05:53,470
life in the universe

118
00:05:49,750 --> 00:05:56,529
this is slowly disintegrated and fall in

119
00:05:53,470 --> 00:05:59,290
a way as we have learned more about the

120
00:05:56,529 --> 00:06:01,299
ways in which planets can be in a way

121
00:05:59,290 --> 00:06:04,960
constructed in a different way so that

122
00:06:01,300 --> 00:06:07,389
they can reduce a bit of habitat

123
00:06:04,959 --> 00:06:09,279
suitable for life there's another

124
00:06:07,389 --> 00:06:09,539
problem with the M star by the way and

125
00:06:09,279 --> 00:06:12,329
that

126
00:06:09,540 --> 00:06:15,180
that little donut is so close to the

127
00:06:12,329 --> 00:06:17,519
star that even if a planet were in it we

128
00:06:15,180 --> 00:06:20,069
would expect it to keep one face towards

129
00:06:17,519 --> 00:06:23,579
the star just as our moon keeps on face

130
00:06:20,069 --> 00:06:25,290
to the earth and as a result it one side

131
00:06:23,579 --> 00:06:27,659
will be extremely hot the other

132
00:06:25,290 --> 00:06:30,270
extremely cold the cold side would

133
00:06:27,660 --> 00:06:33,210
freeze the atmosphere out and with the

134
00:06:30,269 --> 00:06:35,899
planet would become uninhabitable but

135
00:06:33,209 --> 00:06:39,120
we'll see that all of that is changing

136
00:06:35,899 --> 00:06:42,659
so we have this basic picture and what

137
00:06:39,120 --> 00:06:45,180
we do is take a star and we compute the

138
00:06:42,660 --> 00:06:47,070
size of the habitable zone and we see

139
00:06:45,180 --> 00:06:49,829
what planets might be in that habitable

140
00:06:47,069 --> 00:06:52,589
zone if we do that for the earth we get

141
00:06:49,829 --> 00:06:54,539
a picture as you see here here we see

142
00:06:52,589 --> 00:06:56,129
the distance from the Sun and

143

00:06:54,540 --> 00:06:59,550
astronomical units which is the distance

144
00:06:56,129 --> 00:07:04,860
of the Earth to the Sun and here are the

145
00:06:59,550 --> 00:07:07,379
various masses of stars and their types

146
00:07:04,860 --> 00:07:10,069
are shown here here's the G star here's

147
00:07:07,379 --> 00:07:15,659
the other star here's the F star and

148
00:07:10,069 --> 00:07:18,360
here is our solar system the height of

149
00:07:15,660 --> 00:07:20,070
one solar mass and here are the planets

150
00:07:18,360 --> 00:07:23,730
of the solar system in their proper

151
00:07:20,069 --> 00:07:25,949
distance from the Sun and here's the

152
00:07:23,730 --> 00:07:27,230
habitable zone which of course gets

153
00:07:25,949 --> 00:07:29,750
closer

154
00:07:27,230 --> 00:07:31,400
to the left here as we can see M stars

155
00:07:29,750 --> 00:07:36,170
and moves outward as for the hotter

156
00:07:31,399 --> 00:07:38,959
stars and we see them at the range of

157
00:07:36,170 --> 00:07:41,870

the G stars from the Sun the habitable

158

00:07:38,959 --> 00:07:44,719

zone is only about so wide and we look

159

00:07:41,870 --> 00:07:47,360

at that in a way it's both encouraging

160

00:07:44,720 --> 00:07:49,700

because the earth is in it so that's

161

00:07:47,360 --> 00:07:53,270

good news the earth is habitable which

162

00:07:49,699 --> 00:07:55,129

we've actually always have suspected but

163

00:07:53,269 --> 00:07:58,279

the planet Venus is just a little bit

164

00:07:55,129 --> 00:08:01,310

inside the chemical zone probably too

165

00:07:58,279 --> 00:08:04,549

hot and Mars is just about outside the

166

00:08:01,310 --> 00:08:08,660

habitable zone too cold now this is all

167

00:08:04,550 --> 00:08:10,639

based on a very oversimplified idea and

168

00:08:08,660 --> 00:08:12,920

that is that the surface of planets is

169

00:08:10,639 --> 00:08:14,689

concerned is controlled strictly by the

170

00:08:12,920 --> 00:08:17,390

amount of sunlight that falls on them

171

00:08:14,689 --> 00:08:19,759

the sunlight falls on the surface it

172
00:08:17,389 --> 00:08:23,839
warms it up as it worms the surface

173
00:08:19,759 --> 00:08:27,289
reradiates by Planck radiation until the

174
00:08:23,839 --> 00:08:29,839
temperature of the surface stabilizes at

175
00:08:27,290 --> 00:08:31,970
such a temperature that the radiated

176
00:08:29,839 --> 00:08:36,470
energy just balances the incoming solar

177
00:08:31,970 --> 00:08:38,180
energy and that is how we determine the

178
00:08:36,470 --> 00:08:40,750
temperatures of the planets and whether

179
00:08:38,179 --> 00:08:43,969
they should be in the habitable zone

180
00:08:40,750 --> 00:08:46,070
well in that simple picture as you'll

181
00:08:43,970 --> 00:08:48,519
see here there's probably perhaps only

182
00:08:46,070 --> 00:08:50,990
one habitable planet in the solar system

183
00:08:48,519 --> 00:08:52,759
and that picture I just gave you as an

184
00:08:50,990 --> 00:08:55,610
old one that goes back about 20 years

185
00:08:52,759 --> 00:08:58,069
and as I'm about to tell you there have

186
00:08:55,610 --> 00:09:02,480
been a lot of very good surprises since

187
00:08:58,070 --> 00:09:04,090
and all in a way increasing the number

188
00:09:02,480 --> 00:09:10,090
of planets that are habitable

189
00:09:04,090 --> 00:09:14,139
and in particular we will see that our

190
00:09:10,090 --> 00:09:17,320
solar system is very revealing in fact I

191
00:09:14,139 --> 00:09:19,929
like to call us the lessons from the

192
00:09:17,320 --> 00:09:23,560
solar system things in the solar system

193
00:09:19,929 --> 00:09:25,120
itself which tells us about phenomena

194
00:09:23,559 --> 00:09:28,539
which will greatly increase the

195
00:09:25,120 --> 00:09:31,570
habitable zone in our galaxy

196
00:09:28,539 --> 00:09:33,939
and continuous inity of various stars

197
00:09:31,570 --> 00:09:40,120
well the first lesson from the solar

198
00:09:33,940 --> 00:09:43,300
system comes from this planet which is

199
00:09:40,120 --> 00:09:44,950
the planet Venus in principle a planet

200

00:09:43,299 --> 00:09:48,129
almost identical to the earth it's the

201
00:09:44,950 --> 00:09:49,629
same size the same mass one major

202
00:09:48,129 --> 00:09:51,490
difference though and that is its

203
00:09:49,629 --> 00:09:54,669
atmosphere rather than being of one

204
00:09:51,490 --> 00:09:56,500
atmospheric pressure is more like 100

205
00:09:54,669 --> 00:10:00,189
times the atmospheric pressure of the

206
00:09:56,500 --> 00:10:04,000
earth and is mostly carbon dioxide well

207
00:10:00,190 --> 00:10:08,430
we know from observations and from

208
00:10:04,000 --> 00:10:08,429
Landers in which you have gone to Venus

209
00:10:09,389 --> 00:10:15,699
the temperature on Venus is not close to

210
00:10:12,940 --> 00:10:18,310
that of the earth but in fact more than

211
00:10:15,700 --> 00:10:20,070
double the atmospheric or the

212
00:10:18,309 --> 00:10:22,569
temperature on the surface of the earth

213
00:10:20,070 --> 00:10:25,629
the mean temperature on the surface of

214
00:10:22,570 --> 00:10:28,180

the earth is about 300 degrees Kelvin in

215

00:10:25,629 --> 00:10:31,360

the case of Venus it's more like 750

216

00:10:28,179 --> 00:10:34,059

degrees Kelvin and that's an enormous

217

00:10:31,360 --> 00:10:36,370

difference well what's happening here

218

00:10:34,059 --> 00:10:38,469

clearly that simple picture I gave you

219

00:10:36,370 --> 00:10:40,360

of the Sun heating the surface and did

220

00:10:38,470 --> 00:10:42,580

everything coming into balance is not

221

00:10:40,360 --> 00:10:46,810

update doesn't does not apply to Venus

222

00:10:42,580 --> 00:10:50,530

and why is that it's because we have not

223

00:10:46,809 --> 00:10:52,839

taken to effect properly the activity of

224

00:10:50,529 --> 00:10:53,949

the atmosphere in controlling the

225

00:10:52,840 --> 00:10:55,540

temperature

226

00:10:53,950 --> 00:10:57,820

and when you have a massive atmosphere

227

00:10:55,539 --> 00:11:01,120

to do in Venus it can have an enormous

228

00:10:57,820 --> 00:11:04,200

effect on the temperatures and chemical

229
00:11:01,120 --> 00:11:07,120
processes and all arrest in a planet

230
00:11:04,200 --> 00:11:08,950
well what's different about Venus it's

231
00:11:07,120 --> 00:11:12,639
got that very deep atmospheric carbon

232
00:11:08,950 --> 00:11:15,519
dioxide but one other thing and that is

233
00:11:12,639 --> 00:11:18,100
that the temperature at the cloud tops

234
00:11:15,519 --> 00:11:20,769
which is what you're looking at here is

235
00:11:18,100 --> 00:11:22,899
the temperature at a surface which is

236
00:11:20,769 --> 00:11:24,570
not the surface of the planet but a

237
00:11:22,899 --> 00:11:28,929
surface which is about 50 kilometers

238
00:11:24,570 --> 00:11:30,399
above the surface of Venus and that

239
00:11:28,929 --> 00:11:33,009
makes a big difference

240
00:11:30,399 --> 00:11:34,720
two things are going on here one is the

241
00:11:33,009 --> 00:11:36,370
carbon dioxide creates a greenhouse

242
00:11:34,720 --> 00:11:38,800
effect about which we've heard a great

243
00:11:36,370 --> 00:11:41,919
deal but the second about what you don't

244
00:11:38,799 --> 00:11:43,929
hear a great deal is the result of

245
00:11:41,919 --> 00:11:45,578
another very simple lesson that we've

246
00:11:43,929 --> 00:11:48,969
all learned from the solar system

247
00:11:45,578 --> 00:11:51,958
without realizing it and I don't want to

248
00:11:48,970 --> 00:11:51,959
turn off the computer

249
00:11:55,889 --> 00:12:02,019
and that is a lesson we learn every time

250
00:12:00,159 --> 00:12:05,469
we look at a very large amount

251
00:12:02,019 --> 00:12:07,299
this is mount Fujiyama in japan and you

252
00:12:05,470 --> 00:12:09,730
say oh i don't see anything special here

253
00:12:07,299 --> 00:12:11,289
but in fact you do there's not snow

254
00:12:09,730 --> 00:12:13,180
everywhere on this mountain

255
00:12:11,289 --> 00:12:16,028
typically on mountains there isn't snow

256
00:12:13,179 --> 00:12:19,479
everywhere where is the snow it's always

257

00:12:16,028 --> 00:12:22,838
at the top and not at the bottom a very

258
00:12:19,480 --> 00:12:25,480
simple but profound observation when you

259
00:12:22,839 --> 00:12:27,399
go up a mountain it gets colder or when

260
00:12:25,480 --> 00:12:29,769
you come down a mountain it gets warmer

261
00:12:27,399 --> 00:12:33,159
you've never seen snow on the bottom of

262
00:12:29,769 --> 00:12:34,808
the mountain and no snow on the top well

263
00:12:33,159 --> 00:12:37,269
what's that telling us it's telling us

264
00:12:34,808 --> 00:12:39,789
what I just told you go up gets colder

265
00:12:37,269 --> 00:12:43,120
come down it gets warmer and why is that

266
00:12:39,789 --> 00:12:46,149
it's a result of very basic astrophysics

267
00:12:43,120 --> 00:12:47,740
the fact that as a body moves up and

268
00:12:46,149 --> 00:12:49,539
down in a gravitational field the

269
00:12:47,740 --> 00:12:53,379
gravitational field doesn't work on it

270
00:12:49,539 --> 00:12:55,929
so in case of a mountain is a parcel of

271
00:12:53,379 --> 00:12:57,899

air moves downwards the gravitational

272

00:12:55,929 --> 00:13:00,789

field the earth does work on it and

273

00:12:57,899 --> 00:13:02,649

introduces energy which causes the

274

00:13:00,789 --> 00:13:05,498

molecules to move faster and we have a

275

00:13:02,649 --> 00:13:09,600

higher temperature and similarly air

276

00:13:05,499 --> 00:13:12,639

moves upwards the gravitational field

277

00:13:09,600 --> 00:13:16,528

subtracts energy from the parcel of gas

278

00:13:12,639 --> 00:13:20,769

and causes the temperature to go down so

279

00:13:16,528 --> 00:13:23,198

if the radiating surface is in balance

280

00:13:20,769 --> 00:13:25,558

with the radiation from the Sun is high

281

00:13:23,198 --> 00:13:28,058

above the actual surface of the planet

282

00:13:25,558 --> 00:13:30,818

the surface of the planet can be much

283

00:13:28,058 --> 00:13:32,980

warmer than the temperature at the ping

284

00:13:30,818 --> 00:13:35,259

radiates that layer the cloud layer

285

00:13:32,980 --> 00:13:37,709

which is in the radiative equilibrium

286
00:13:35,259 --> 00:13:41,470
with the light coming from the Sun and

287
00:13:37,708 --> 00:13:43,419
it is by this route that the temperature

288
00:13:41,470 --> 00:13:46,540
at the cloud level of Venus which is

289
00:13:43,419 --> 00:13:46,979
about is in this room becomes as you go

290
00:13:46,539 --> 00:13:50,899
50

291
00:13:46,980 --> 00:13:53,250
Kalama to the surface 750 degrees well

292
00:13:50,899 --> 00:13:55,620
could that be it's the same thing to be

293
00:13:53,250 --> 00:13:58,230
happening in other planets well indeed

294
00:13:55,620 --> 00:14:00,379
it does in all of the planets with

295
00:13:58,230 --> 00:14:02,519
massive atmospheres in the solar system

296
00:14:00,379 --> 00:14:05,129
whether there are mountains there or not

297
00:14:02,519 --> 00:14:07,589
the temperature goes up as you go down

298
00:14:05,129 --> 00:14:10,169
in the atmosphere so if you were in the

299
00:14:07,589 --> 00:14:12,930
atmosphere of Jupiter and this is a

300
00:14:10,169 --> 00:14:15,299
artists depiction of that atmosphere as

301
00:14:12,929 --> 00:14:17,489
you go down as one of our probes

302
00:14:15,299 --> 00:14:20,278
actually did you would see the

303
00:14:17,490 --> 00:14:22,649
temperature continuously rising until

304
00:14:20,278 --> 00:14:24,328
you come to levels where you get ammonia

305
00:14:22,649 --> 00:14:25,980
clouds and you go farther down and you

306
00:14:24,328 --> 00:14:28,620
get ammonium chloride clouds and go

307
00:14:25,980 --> 00:14:31,230
farther down and finally fire you reach

308
00:14:28,620 --> 00:14:34,909
the point where water clouds are in

309
00:14:31,230 --> 00:14:38,039
present and one layer after another of

310
00:14:34,909 --> 00:14:42,208
clouds made from different constituents

311
00:14:38,039 --> 00:14:45,509
up here now an important point there for

312
00:14:42,208 --> 00:14:48,239
in the consideration of life is that at

313
00:14:45,509 --> 00:14:50,970
some level the temperature is going to

314

00:14:48,240 --> 00:14:53,579
be right for liquid water the stuff the

315
00:14:50,970 --> 00:14:55,319
basic stuff of life and indeed we've

316
00:14:53,578 --> 00:14:57,239
actually our probes have actually reach

317
00:14:55,318 --> 00:14:59,698
that level our radio telescopes have

318
00:14:57,240 --> 00:15:01,079
seen that level it's actually at a place

319
00:14:59,698 --> 00:15:02,759
in the atmosphere where the pressure is

320
00:15:01,078 --> 00:15:05,429
about one atmosphere about us in this

321
00:15:02,759 --> 00:15:07,289
room and if you were there you would be

322
00:15:05,429 --> 00:15:09,989
pretty comfortable except there's no

323
00:15:07,289 --> 00:15:11,578
oxygen unfortunately but at least the

324
00:15:09,990 --> 00:15:14,959
temperature be right and there could be

325
00:15:11,578 --> 00:15:17,789
liquid water could there be life here I

326
00:15:14,958 --> 00:15:19,198
mean this is a zone where the conditions

327
00:15:17,789 --> 00:15:21,719
are right for life there's lots of

328
00:15:19,198 --> 00:15:25,469

organic molecules there is energy from

329

00:15:21,720 --> 00:15:28,110

the Sun there's water and perhaps there

330

00:15:25,470 --> 00:15:29,670

is and a thing always to keep in mind

331

00:15:28,110 --> 00:15:32,159

when you're considering extraterrestrial

332

00:15:29,669 --> 00:15:33,729

life is that life is very opportunistic

333

00:15:32,159 --> 00:15:37,100

and

334

00:15:33,730 --> 00:15:39,950

adaptable one of the great strengths of

335

00:15:37,100 --> 00:15:43,278

life is that it can adapt to many

336

00:15:39,950 --> 00:15:45,320

extreme conditions as we see by finding

337

00:15:43,278 --> 00:15:47,838

life in these boat of the Arctic oceans

338

00:15:45,320 --> 00:15:50,180

life on the top of Mount Everest just

339

00:15:47,839 --> 00:15:53,180

about everywhere on earth where life

340

00:15:50,179 --> 00:16:03,739

could exist now this is a speculation

341

00:15:53,179 --> 00:16:07,789

but some and some astronomers have

342

00:16:03,740 --> 00:16:11,389

suggested in the deed life may arise in

343
00:16:07,789 --> 00:16:13,519
such a level and for it to survive it

344
00:16:11,389 --> 00:16:15,588
must continue to be at that altitude

345
00:16:13,519 --> 00:16:17,778
otherwise if it grows up it will freeze

346
00:16:15,589 --> 00:16:20,480
if it goes down and will get boiled or

347
00:16:17,778 --> 00:16:22,088
sterilized and so it was proposed by

348
00:16:20,480 --> 00:16:25,100
none other than Carl Sagan

349
00:16:22,089 --> 00:16:26,570
one of the first papers of this kind

350
00:16:25,100 --> 00:16:28,970
ever published in the Astrophysical

351
00:16:26,570 --> 00:16:31,640
Journal that there could well be in the

352
00:16:28,970 --> 00:16:33,470
atmospheres of giant planets and all of

353
00:16:31,639 --> 00:16:36,458
them by the way have levels where the

354
00:16:33,470 --> 00:16:38,810
temperature is suitable for life

355
00:16:36,458 --> 00:16:41,899
creatures which you've evolved first is

356
00:16:38,809 --> 00:16:44,659
very primitive microbes have floated at

357
00:16:41,899 --> 00:16:47,179
the right altitude and in time is a

358
00:16:44,659 --> 00:16:49,579
survival mechanism have been developed

359
00:16:47,179 --> 00:16:51,349
sort of balloon-like structures which

360
00:16:49,580 --> 00:16:54,770
allow them to maintain their altitude

361
00:16:51,350 --> 00:16:56,899
and live a happy life they call them

362
00:16:54,769 --> 00:16:59,720
floaters and this is a picture of what

363
00:16:56,899 --> 00:17:02,449
floaters might look like a speculation

364
00:16:59,720 --> 00:17:06,709
but it's reminding us that the universe

365
00:17:02,450 --> 00:17:08,568
is not only stranger than we imagine

366
00:17:06,709 --> 00:17:11,350
it's stranger than we can imagine and

367
00:17:08,568 --> 00:17:14,269
perhaps things like this actually exist

368
00:17:11,349 --> 00:17:15,889
the main point here is that when you

369
00:17:14,269 --> 00:17:18,259
ever you have a deep atmosphere you will

370
00:17:15,890 --> 00:17:20,000
have a level suitable for life if there

371

00:17:18,259 --> 00:17:23,720
happens to be a mountain there

372
00:17:20,000 --> 00:17:26,000
laughs as in this Hardison something it

373
00:17:23,720 --> 00:17:28,730
can be populated even though the planet

374
00:17:26,000 --> 00:17:32,929
is very far from its star far outside

375
00:17:28,730 --> 00:17:35,960
the range of that basic canonical

376
00:17:32,929 --> 00:17:41,600
canonical habitable zone I showed you in

377
00:17:35,960 --> 00:17:43,669
the very early slides well not only an

378
00:17:41,599 --> 00:17:45,649
atmosphere can cause the same effect

379
00:17:43,669 --> 00:17:47,150
providing you a level where the

380
00:17:45,650 --> 00:17:50,690
temperatures are right for life

381
00:17:47,150 --> 00:17:53,059
but so can something else ice for

382
00:17:50,690 --> 00:17:54,500
example this may look like a blurry

383
00:17:53,058 --> 00:17:58,668
picture but it's a picture of the

384
00:17:54,500 --> 00:18:00,829
satellite Europa of Jupiter almost

385
00:17:58,669 --> 00:18:02,900

featureless you can see a few small

386

00:18:00,829 --> 00:18:05,178

markings there but none of the great

387

00:18:02,900 --> 00:18:07,548

fields of craters we see on most objects

388

00:18:05,179 --> 00:18:10,460

in the solar system when we look closer

389

00:18:07,548 --> 00:18:13,759

we find that this surface whose spectrum

390

00:18:10,460 --> 00:18:17,509

is that of water ice this is all frozen

391

00:18:13,759 --> 00:18:20,599

ice is fairly complicated but in

392

00:18:17,509 --> 00:18:24,650

particular you can see that this ice is

393

00:18:20,599 --> 00:18:26,629

frozen surface at times is broken up and

394

00:18:24,650 --> 00:18:28,759

you find pieces floating around that

395

00:18:26,630 --> 00:18:30,470

used to fit together like pieces of a

396

00:18:28,759 --> 00:18:32,750

crossword puzzle you see a place here

397

00:18:30,470 --> 00:18:35,089

that used to match and what this is

398

00:18:32,750 --> 00:18:37,519

telling us is that occasionally the

399

00:18:35,089 --> 00:18:42,319

surface of Europa where the temperature

400
00:18:37,519 --> 00:18:45,589
is about 150 below zero Celsius at times

401
00:18:42,319 --> 00:18:48,379
becomes at least slushy and the surface

402
00:18:45,589 --> 00:18:50,269
breaks up and moves around and we see

403
00:18:48,380 --> 00:18:50,890
that in the presence of these icebergs

404
00:18:50,269 --> 00:18:54,429
we

405
00:18:50,890 --> 00:18:58,000
now there icebergs in there now locked

406
00:18:54,429 --> 00:19:00,880
in the frozen slush which is at the

407
00:18:58,000 --> 00:19:02,589
present time solid everywhere well how

408
00:19:00,880 --> 00:19:04,960
big is this this is about a kilometre

409
00:19:02,589 --> 00:19:08,349
across so these these are all about one

410
00:19:04,960 --> 00:19:12,220
kilometre and we have shadows here from

411
00:19:08,349 --> 00:19:15,639
which we can deduce the thickness of the

412
00:19:12,220 --> 00:19:17,798
ice of these icebergs and we know that

413
00:19:15,640 --> 00:19:21,520
because it's about 90% of an iceberg is

414
00:19:17,798 --> 00:19:22,869
below the surface and about 10% above so

415
00:19:21,519 --> 00:19:24,940
if we can measure the height which we

416
00:19:22,869 --> 00:19:27,039
can do by measuring these shadows and

417
00:19:24,940 --> 00:19:29,350
knowing the geometry of the Sun when

418
00:19:27,039 --> 00:19:32,589
this picture was taken we can deduce

419
00:19:29,349 --> 00:19:36,159
that these ice icebergs are in fact

420
00:19:32,589 --> 00:19:40,149
about ten kilometers thick so that in

421
00:19:36,160 --> 00:19:45,070
fact the surface of Europa is about ten

422
00:19:40,150 --> 00:19:49,090
kilometers thick of ice everywhere on

423
00:19:45,069 --> 00:19:54,009
the planet and what's amazing about that

424
00:19:49,089 --> 00:19:57,308
is that below that ice cap there is

425
00:19:54,009 --> 00:20:00,970
liquid water if the ice is thick enough

426
00:19:57,308 --> 00:20:03,639
to insulate the water beneath it to a

427
00:20:00,970 --> 00:20:06,700
sufficient degree that the water beneath

428

00:20:03,640 --> 00:20:09,480
is above the freezing point and as

429
00:20:06,700 --> 00:20:11,610
liquid warm by the way by tidal

430
00:20:09,480 --> 00:20:14,679
interactions with the planet and from

431
00:20:11,609 --> 00:20:17,918
residual heat from the formation of the

432
00:20:14,679 --> 00:20:19,509
satellite I'm sorry it's a satellite how

433
00:20:17,919 --> 00:20:21,580
thick is the water underneath we know

434
00:20:19,509 --> 00:20:23,798
that from measurements of the mass of

435
00:20:21,579 --> 00:20:25,808
Europa its density and also some other

436
00:20:23,798 --> 00:20:29,500
measurements of electrical currents in

437
00:20:25,808 --> 00:20:31,869
the ocean beneath it it turns out the

438
00:20:29,500 --> 00:20:34,929
ocean of Europa is at least 100

439
00:20:31,869 --> 00:20:37,919
kilometers deep probably 200 kilometers

440
00:20:34,929 --> 00:20:40,680
deep very deep ocean

441
00:20:37,920 --> 00:20:45,060
the ocean of the earth on average is 2.5

442
00:20:40,680 --> 00:20:47,940

kilometres deep on Europa is 100

443

00:20:45,059 --> 00:20:52,500

kilometres perhaps 200 in any case there

444

00:20:47,940 --> 00:20:55,500

is more liquid water on Europa than in

445

00:20:52,500 --> 00:20:58,470

all the oceans of earth there is also

446

00:20:55,500 --> 00:21:01,619

organic compounds there delivered by

447

00:20:58,470 --> 00:21:07,799

meteorites comet collisions from black

448

00:21:01,619 --> 00:21:11,609

smokers in the water and there is a

449

00:21:07,799 --> 00:21:14,099

thermal energy from the tidal forces and

450

00:21:11,609 --> 00:21:17,849

title distortions of the satellite and

451

00:21:14,099 --> 00:21:20,279

so what we have here is thermal

452

00:21:17,849 --> 00:21:25,919

insulation provided in this case not by

453

00:21:20,279 --> 00:21:28,079

air but by ice frozen water and one of

454

00:21:25,920 --> 00:21:30,300

the wonders of all of our universe is

455

00:21:28,079 --> 00:21:32,909

that water is one of the few things that

456

00:21:30,299 --> 00:21:35,940

expands when it freezes and therefore

457
00:21:32,910 --> 00:21:38,130
floats so the result is when we make up

458
00:21:35,940 --> 00:21:40,710
when ice is formed on place like Europa

459
00:21:38,130 --> 00:21:43,950
it does float to the surface and starts

460
00:21:40,710 --> 00:21:47,490
to provide an insulating layer in fact

461
00:21:43,950 --> 00:21:48,900
as you see here that 10 kilometer of

462
00:21:47,490 --> 00:21:50,519
water ice provides about the same

463
00:21:48,900 --> 00:21:51,990
thermal insulation is about a hundred

464
00:21:50,519 --> 00:21:53,839
meters of the standard fiberglass

465
00:21:51,990 --> 00:21:56,279
insulation we use when we build houses

466
00:21:53,839 --> 00:21:57,599
or you can achieve the same thing with

467
00:21:56,279 --> 00:22:00,599
two and a half kilometers of brick or

468
00:21:57,599 --> 00:22:03,539
concrete so for those of you who are

469
00:22:00,599 --> 00:22:05,789
real estate speculators you might

470
00:22:03,539 --> 00:22:07,259
contemplate housing developments on

471
00:22:05,789 --> 00:22:09,960
Europa because you could build them on

472
00:22:07,259 --> 00:22:11,788
the surface it's just the roofs are

473
00:22:09,960 --> 00:22:14,159
going to be quite thick they have to be

474
00:22:11,788 --> 00:22:16,408
100 metres thick and insulation and they

475
00:22:14,159 --> 00:22:19,019
will be warm and cozy inside and you

476
00:22:16,409 --> 00:22:23,609
have a certainly an ample support source

477
00:22:19,019 --> 00:22:27,048
of water and would be about the same as

478
00:22:23,608 --> 00:22:30,478
living in the arctic conditions

479
00:22:27,048 --> 00:22:32,788
well liquid water the temperature is

480
00:22:30,479 --> 00:22:35,100
very near the freezing point but it is

481
00:22:32,788 --> 00:22:38,158
liquid and we know on earth that

482
00:22:35,099 --> 00:22:39,748
creatures live in free in water that is

483
00:22:38,159 --> 00:22:41,940
close to the freezing point in fact the

484
00:22:39,749 --> 00:22:45,118
Arctic oceans and the oceans around

485

00:22:41,940 --> 00:22:47,070
Antarctica are one of the richest areas

486
00:22:45,118 --> 00:22:51,689
on earth when it comes to the amount of

487
00:22:47,069 --> 00:22:54,048
animal and plant life so what might be

488
00:22:51,690 --> 00:22:56,940
in the ocean of Europa we wish we knew

489
00:22:54,048 --> 00:23:00,358
because this is a really serious test

490
00:22:56,940 --> 00:23:02,460
case for the ubiquity of life in planets

491
00:23:00,358 --> 00:23:05,668
it should there really should be some

492
00:23:02,460 --> 00:23:07,858
life in the ocean of Europa and what

493
00:23:05,669 --> 00:23:10,139
might it look like it brought a few

494
00:23:07,858 --> 00:23:13,079
things along here which I think pictures

495
00:23:10,138 --> 00:23:15,358
I think which suggest to you what we

496
00:23:13,079 --> 00:23:17,358
might find in some of these places the

497
00:23:15,358 --> 00:23:21,148
case of Europa one of my favorites

498
00:23:17,358 --> 00:23:23,908
candidates for life on Europa fed by the

499
00:23:21,148 --> 00:23:26,959

way by the energy and nutrients that

500

00:23:23,909 --> 00:23:30,210

come out of the deep sea vents is this

501

00:23:26,960 --> 00:23:33,569

it's called a cone jelly many of you are

502

00:23:30,210 --> 00:23:36,960

scenic own jelly I don't know if hold up

503

00:23:33,569 --> 00:23:40,678

your hand anybody seen a cone jelly well

504

00:23:36,960 --> 00:23:41,840

that's too bad Joe cone jellies from

505

00:23:40,679 --> 00:23:44,429

your name you can tell they're like a

506

00:23:41,839 --> 00:23:46,709

jellyfish but they're slightly different

507

00:23:44,429 --> 00:23:48,869

the difference is almost trivial the

508

00:23:46,710 --> 00:23:49,319

differences that the tentacles of a cone

509

00:23:48,868 --> 00:23:51,478

jelly

510

00:23:49,319 --> 00:23:54,178

do not have toxins in them they're used

511

00:23:51,479 --> 00:23:56,500

simply to separate food into the mouth

512

00:23:54,179 --> 00:24:00,670

of the cone jelly which is

513

00:23:56,500 --> 00:24:03,400

here in true-true jellyfish the

514
00:24:00,670 --> 00:24:05,019
tentacles I'll have toxins in them Tony

515
00:24:03,400 --> 00:24:08,370
comb jellies are extremely beautiful

516
00:24:05,019 --> 00:24:11,500
because that the the cones

517
00:24:08,369 --> 00:24:13,269
Coulson sorry I put the wrong word here

518
00:24:11,500 --> 00:24:15,279
I'm sorry it's a comb jelly seal a

519
00:24:13,269 --> 00:24:16,990
beautiful comb jelly

520
00:24:15,279 --> 00:24:21,000
there are comas which are just like hair

521
00:24:16,990 --> 00:24:24,430
combs and they move to propel the

522
00:24:21,000 --> 00:24:27,369
creature in the water and it turns out

523
00:24:24,430 --> 00:24:32,650
these cones are consistent with effect

524
00:24:27,369 --> 00:24:36,129
as a many Tufts of hair which resemble a

525
00:24:32,650 --> 00:24:38,050
hair comb we use with our comb and as

526
00:24:36,130 --> 00:24:40,360
these move they act like diffraction

527
00:24:38,049 --> 00:24:44,289
gratings that create very colorful

528
00:24:40,359 --> 00:24:46,059
things you see what it is they're about

529
00:24:44,289 --> 00:24:49,359
eight centimeters in size by the way

530
00:24:46,059 --> 00:24:50,980
they're not small and this is one of the

531
00:24:49,359 --> 00:24:53,619
most common creatures found in the

532
00:24:50,980 --> 00:24:55,420
Arctic Ocean on the earth you could take

533
00:24:53,619 --> 00:24:57,219
this right now and put it in the ocean

534
00:24:55,420 --> 00:25:01,330
of your elbow and it would be perfectly

535
00:24:57,220 --> 00:25:03,549
happy and so perhaps something like this

536
00:25:01,329 --> 00:25:05,559
actually exists out there and NASA would

537
00:25:03,549 --> 00:25:08,559
love to run a mission to determine if

538
00:25:05,559 --> 00:25:12,329
that's true there about a hundred

539
00:25:08,559 --> 00:25:14,829
different species of comb jolly and

540
00:25:12,329 --> 00:25:16,480
they're all very beautiful in the way

541
00:25:14,829 --> 00:25:19,210
you see here here's another picture of

542

00:25:16,480 --> 00:25:20,420
that same species slightly different

543
00:25:19,210 --> 00:25:26,279
lighting effects

544
00:25:20,420 --> 00:25:28,350
this is what it looks like now that

545
00:25:26,279 --> 00:25:33,420
shows us we have an abode of life far

546
00:25:28,349 --> 00:25:36,058
outside the canonical habitable zone in

547
00:25:33,420 --> 00:25:39,300
this case brought about by an insulating

548
00:25:36,058 --> 00:25:42,180
layer of ice another place where this

549
00:25:39,299 --> 00:25:45,000
might exist is farther out in the solar

550
00:25:42,180 --> 00:25:48,509
system where the Cassini spacecraft

551
00:25:45,000 --> 00:25:51,630
shown here has made many important

552
00:25:48,509 --> 00:25:54,089
discoveries one of them not having to do

553
00:25:51,630 --> 00:25:58,650
with life as we know it was discoveries

554
00:25:54,089 --> 00:26:00,629
of the satellite Titan of Saturn and

555
00:25:58,650 --> 00:26:02,970
this is what it looks like it has an

556
00:26:00,630 --> 00:26:04,830

atmosphere whose that Missouri pressure

557

00:26:02,970 --> 00:26:06,720

is about the same as here on earth but

558

00:26:04,829 --> 00:26:09,029

it is made and as mainly nitrogen is

559

00:26:06,720 --> 00:26:12,299

very much like our atmosphere except

560

00:26:09,029 --> 00:26:14,819

there is no oxygen there are many

561

00:26:12,299 --> 00:26:18,629

hydrocarbons yet the atmosphere of Titan

562

00:26:14,819 --> 00:26:20,549

is very rich in hydrocarbons and related

563

00:26:18,630 --> 00:26:24,179

molecules which give it this orange cast

564

00:26:20,549 --> 00:26:27,899

you see here and we have sent a a probe

565

00:26:24,179 --> 00:26:29,429

to it the Huygens probe which showed

566

00:26:27,900 --> 00:26:31,019

that it has continents and as you can

567

00:26:29,429 --> 00:26:33,630

see dark areas here which looked like

568

00:26:31,019 --> 00:26:35,519

lakes and these are thought to be lakes

569

00:26:33,630 --> 00:26:38,130

of hydrocarbons because the temperature

570

00:26:35,519 --> 00:26:40,160

here is about 100 degrees Kelvin which

571
00:26:38,130 --> 00:26:43,080
means that all the water is frozen out

572
00:26:40,160 --> 00:26:46,890
but this could these could very well be

573
00:26:43,079 --> 00:26:50,609
lakes of methane propane butane the

574
00:26:46,890 --> 00:26:53,429
things you used to heat your house in

575
00:26:50,609 --> 00:26:54,178
some cases farther out there's a

576
00:26:53,429 --> 00:26:56,720
satellite

577
00:26:54,179 --> 00:26:59,330
oh yeah pitous

578
00:26:56,720 --> 00:27:01,640
actually not further out it's a farther

579
00:26:59,329 --> 00:27:03,949
up from Saturn it's a saddle us the

580
00:27:01,640 --> 00:27:06,320
satellite of Saturn which we learned

581
00:27:03,950 --> 00:27:08,419
actually has geysers of water coming off

582
00:27:06,319 --> 00:27:10,908
the surface here photographed by the

583
00:27:08,419 --> 00:27:14,210
iPad by this icon out by these

584
00:27:10,909 --> 00:27:16,100
Cassini spacecraft geysers of water

585
00:27:14,210 --> 00:27:18,470
going hundreds of kilometers above the

586
00:27:16,099 --> 00:27:20,329
surface showing us that there must be

587
00:27:18,470 --> 00:27:23,298
liquid water close to the surface here

588
00:27:20,329 --> 00:27:27,168
where again the surface temperature

589
00:27:23,298 --> 00:27:33,308
should be about 150 degrees below zero

590
00:27:27,169 --> 00:27:36,350
Celsius and yet there is the water now

591
00:27:33,308 --> 00:27:38,750
that tells us that something probably a

592
00:27:36,349 --> 00:27:40,788
nice insulating layer is keeping

593
00:27:38,750 --> 00:27:43,250
providing a habitable zone we don't know

594
00:27:40,788 --> 00:27:45,470
how big even here at the distance of

595
00:27:43,250 --> 00:27:47,569
Saturn the distance of Saturn the

596
00:27:45,470 --> 00:27:50,450
sunlight is only 1% of what it is on

597
00:27:47,569 --> 00:27:52,460
earth and so the surface temperatures

598
00:27:50,450 --> 00:27:55,220
are very very cold but with an

599

00:27:52,460 --> 00:27:58,250
insulating layer thick enough you can

600
00:27:55,220 --> 00:28:02,329
have conditions suitable for life now

601
00:27:58,250 --> 00:28:04,250
what about the M stars those stars which

602
00:28:02,329 --> 00:28:06,079
are so common and yet to have these

603
00:28:04,250 --> 00:28:10,538
problems of the very small habitable

604
00:28:06,079 --> 00:28:13,689
zone possibility of of

605
00:28:10,538 --> 00:28:15,878
being in synchronous rotation so they

606
00:28:13,690 --> 00:28:18,669
keep one face towards the stars you see

607
00:28:15,878 --> 00:28:22,178
this hardest concept the other side in

608
00:28:18,669 --> 00:28:24,909
the dark and if it is a case there

609
00:28:22,179 --> 00:28:27,699
you know wrote rotating at the same rate

610
00:28:24,909 --> 00:28:31,059
as they go around their star means the

611
00:28:27,699 --> 00:28:33,909
situation you see here and what will

612
00:28:31,058 --> 00:28:36,398
happen here is the air will heat it will

613
00:28:33,909 --> 00:28:38,979

blow rise lower onto the backside where

614

00:28:36,398 --> 00:28:41,168

it freezes out and very quickly all the

615

00:28:38,979 --> 00:28:44,129

atmosphere will be frozen out and it

616

00:28:41,169 --> 00:28:46,959

will be it will be unsuitable for life

617

00:28:44,128 --> 00:28:48,878

well there are two reasons we know of

618

00:28:46,959 --> 00:28:53,229

why that probably isn't the case after

619

00:28:48,878 --> 00:28:56,318

all first computer modeling of that flow

620

00:28:53,229 --> 00:28:58,209

of air I just described to you has shown

621

00:28:56,318 --> 00:29:01,928

that if the atmospheric pressure is

622

00:28:58,209 --> 00:29:03,609

about one atmosphere or higher there

623

00:29:01,929 --> 00:29:05,949

will be enough heat curve to the

624

00:29:03,608 --> 00:29:08,918

backside to always keep it above the

625

00:29:05,949 --> 00:29:14,259

freezing point of air and so the air

626

00:29:08,919 --> 00:29:15,999

won't freeze out the other reason is one

627

00:29:14,259 --> 00:29:22,538

we've learned is another lesson from the

628
00:29:15,999 --> 00:29:24,669
solar system our planet Mercury is close

629
00:29:22,538 --> 00:29:27,940
enough to the Sun that it should keep

630
00:29:24,669 --> 00:29:29,919
one face to the Sun and for actually a

631
00:29:27,940 --> 00:29:32,459
century so it was believed that this was

632
00:29:29,919 --> 00:29:36,429
the case mercury is very hard to observe

633
00:29:32,459 --> 00:29:39,548
and because of its it's always close to

634
00:29:36,429 --> 00:29:41,489
the Sun but it was thought that mercury

635
00:29:39,548 --> 00:29:44,259
kept one face to the Sun based on

636
00:29:41,489 --> 00:29:48,190
eyeball observations which turned out in

637
00:29:44,259 --> 00:29:50,229
fact that be embellished now we know

638
00:29:48,190 --> 00:29:53,949
from radar observations made at the

639
00:29:50,229 --> 00:29:56,229
Arecibo Observatory that mercury is what

640
00:29:53,949 --> 00:29:58,538
you see here does not keep one face

641
00:29:56,229 --> 00:29:59,739
towards the Sun when facts it does

642
00:29:58,538 --> 00:30:03,098
something very strange

643
00:29:59,739 --> 00:30:05,289
it presents opposite faces of the Sun

644
00:30:03,098 --> 00:30:07,569
every time it comes close to the Sun

645
00:30:05,289 --> 00:30:08,950
I'm saying it comes close you say what

646
00:30:07,569 --> 00:30:10,689
are you talking about we thought the

647
00:30:08,950 --> 00:30:13,000
planets were in orbit with circular

648
00:30:10,690 --> 00:30:15,910
orbits mercury is not in a circular

649
00:30:13,000 --> 00:30:17,740
orbit it is in a highly lit not a highly

650
00:30:15,910 --> 00:30:19,600
elliptical orbit but an elliptical orbit

651
00:30:17,740 --> 00:30:24,059
such that at times it is much close to

652
00:30:19,599 --> 00:30:27,519
the Sun and other times and as a result

653
00:30:24,059 --> 00:30:30,899
as it is close to the Sun is moving very

654
00:30:27,519 --> 00:30:35,619
quickly and title torques actually

655
00:30:30,900 --> 00:30:37,090
control its repre its rotation and in

656

00:30:35,619 --> 00:30:39,789
time have brought it to a situation

657
00:30:37,089 --> 00:30:43,569
where it does what I just described it

658
00:30:39,789 --> 00:30:45,849
keeps one face to the Sun one close pass

659
00:30:43,569 --> 00:30:47,889
to the Sun and the other face faces the

660
00:30:45,849 --> 00:30:50,589
Sun the second time it goes by the Sun

661
00:30:47,890 --> 00:30:57,220
so it is not keeping one face to the Sun

662
00:30:50,589 --> 00:30:59,349
and this means that that eliminates the

663
00:30:57,220 --> 00:31:03,789
possibility atmosphere gets frozen now

664
00:30:59,349 --> 00:31:07,419
it rotates it has seasons day/night just

665
00:31:03,789 --> 00:31:10,990
like any other respectable planet and so

666
00:31:07,420 --> 00:31:14,200
that old picture was wrong as long as

667
00:31:10,990 --> 00:31:16,690
the orbit is elliptical enough and even

668
00:31:14,200 --> 00:31:19,029
if it isn't perhaps the atmospheric

669
00:31:16,690 --> 00:31:22,360
effect I just described to you keeps the

670
00:31:19,029 --> 00:31:26,500

thing habitable anyway but what is the

671

00:31:22,359 --> 00:31:28,329

ellipticity of mercury as described a

672

00:31:26,500 --> 00:31:31,680

thing called the eccentricity by

673

00:31:28,329 --> 00:31:33,730

astronomers and it's about point two

674

00:31:31,680 --> 00:31:35,500

well what do we know about the

675

00:31:33,730 --> 00:31:39,430

extrasolar planets and which we know

676

00:31:35,500 --> 00:31:41,170

above 347 as of today about half of them

677

00:31:39,430 --> 00:31:44,509

have eccentricities higher than point

678

00:31:41,170 --> 00:31:46,879

two and if that rule holds for the

679

00:31:44,509 --> 00:31:49,669

of em stars and of course we don't know

680

00:31:46,878 --> 00:31:51,528

that for sure them we never measure the

681

00:31:49,669 --> 00:31:54,619

eccentricity of the planet of an M star

682

00:31:51,528 --> 00:31:58,429

but if it holds that at least half the M

683

00:31:54,618 --> 00:32:03,528

stars are certainly free of the frozen

684

00:31:58,429 --> 00:32:07,009

out atmosphere now that says then that

685
00:32:03,528 --> 00:32:09,048
this picture may or may not be true but

686
00:32:07,009 --> 00:32:11,598
in fact it doesn't matter much even in

687
00:32:09,048 --> 00:32:15,138
the synchronous case what you have is

688
00:32:11,598 --> 00:32:17,808
one point on the star on the planet that

689
00:32:15,138 --> 00:32:21,828
is facing the star it becomes very hot

690
00:32:17,808 --> 00:32:24,078
as you go towards the big boundary

691
00:32:21,828 --> 00:32:27,318
between night and day it's cooler and

692
00:32:24,078 --> 00:32:30,618
cooler and it's a Goldilocks situation

693
00:32:27,318 --> 00:32:32,538
where it's some zone the temperature

694
00:32:30,618 --> 00:32:35,118
will be just right for life and that's

695
00:32:32,538 --> 00:32:37,249
shown in green here and so in a way

696
00:32:35,118 --> 00:32:39,918
these planets maybe after all the best

697
00:32:37,249 --> 00:32:42,348
possible of bullets for life because

698
00:32:39,919 --> 00:32:45,199
they provide us tremendous range in

699
00:32:42,348 --> 00:32:47,328
temperatures and some where conditions

700
00:32:45,199 --> 00:32:50,058
will be just right for the origins of

701
00:32:47,328 --> 00:32:53,328
life these would be wonderful places to

702
00:32:50,058 --> 00:32:56,928
live the weather is very predictable if

703
00:32:53,328 --> 00:33:00,288
you want to if you're living in the the

704
00:32:56,929 --> 00:33:02,000
habit will ring on the planet and you

705
00:33:00,288 --> 00:33:04,099
want to

706
00:33:02,000 --> 00:33:06,500
tropical vacation you just head towards

707
00:33:04,099 --> 00:33:10,279
the pole it warms up you can go to the

708
00:33:06,500 --> 00:33:12,890
beach and have a little quick vacation

709
00:33:10,279 --> 00:33:14,450
in Hawaii on the other hand if you want

710
00:33:12,890 --> 00:33:17,390
to ski you just go the other direction

711
00:33:14,450 --> 00:33:19,330
and you don't have to go very far before

712
00:33:17,390 --> 00:33:21,560
you will be into a place where

713

00:33:19,329 --> 00:33:24,500
conditions our winter conditions all

714
00:33:21,559 --> 00:33:27,200
year totally predictable the weather

715
00:33:24,500 --> 00:33:32,299
never changes anywhere on such a planet

716
00:33:27,200 --> 00:33:34,400
if they actually exist and there's one

717
00:33:32,299 --> 00:33:37,369
other problem with em Stars I didn't

718
00:33:34,400 --> 00:33:39,009
mention yet and that is most of them are

719
00:33:37,369 --> 00:33:42,799
what are known as flare stars

720
00:33:39,009 --> 00:33:45,049
occasionally they have eruptions of

721
00:33:42,799 --> 00:33:47,089
activity on their surface which cause

722
00:33:45,049 --> 00:33:49,190
them to become much brighter and not by

723
00:33:47,089 --> 00:33:50,809
a little bit not by a few percent but

724
00:33:49,190 --> 00:33:52,850
sometimes they double in brightness for

725
00:33:50,809 --> 00:33:56,269
a time which ranges from minutes to

726
00:33:52,849 --> 00:33:59,209
hours and people have wondered if might

727
00:33:56,269 --> 00:34:01,190

that that might not be lethal for life

728

00:33:59,210 --> 00:34:06,079

and it would be another reason why M

729

00:34:01,190 --> 00:34:08,750

stars are not suitable for life well you

730

00:34:06,079 --> 00:34:11,630

have to remember what I tried to impress

731

00:34:08,750 --> 00:34:15,380

on you earlier life is opportunistic and

732

00:34:11,630 --> 00:34:18,230

adaptable and we already have creatures

733

00:34:15,380 --> 00:34:20,210

on earth like the cone jellies

734

00:34:18,230 --> 00:34:24,019

which are quite suitable to live on

735

00:34:20,210 --> 00:34:27,679

mercury if you want to see one example I

736

00:34:24,019 --> 00:34:30,739

think is a good example there it is

737

00:34:27,679 --> 00:34:32,630

here's the turtle if the star suddenly

738

00:34:30,739 --> 00:34:34,239

lights up the turtle turtle can just

739

00:34:32,630 --> 00:34:37,849

pull into its shell and wait out the

740

00:34:34,239 --> 00:34:41,178

solar flare light and go on its merry

741

00:34:37,849 --> 00:34:44,500

way in fact there's another solution to

742
00:34:41,179 --> 00:34:46,849
students does the star flare crop

743
00:34:44,500 --> 00:34:50,360
which is certainly a good one

744
00:34:46,849 --> 00:34:52,219
and that is if there's bodies of water

745
00:34:50,360 --> 00:34:55,010
all you need to do is jump in the water

746
00:34:52,219 --> 00:34:57,469
and go down a few meters and the water

747
00:34:55,010 --> 00:35:01,310
will protect you you know the water on

748
00:34:57,469 --> 00:35:04,069
earth say the ocean it does not change

749
00:35:01,309 --> 00:35:06,110
from night to day on earth we had full

750
00:35:04,070 --> 00:35:10,130
sunlight for 12 hours and no sunlight

751
00:35:06,110 --> 00:35:11,780
for and for 12 hours that's a bigger

752
00:35:10,130 --> 00:35:15,019
change in brightness that occurs in a

753
00:35:11,780 --> 00:35:16,700
solar flare on an M star and yet the

754
00:35:15,019 --> 00:35:17,869
temperature of the ocean doesn't really

755
00:35:16,699 --> 00:35:21,199
change at all

756
00:35:17,869 --> 00:35:22,789
events like that heaven also being

757
00:35:21,199 --> 00:35:26,089
beneath the surface of the water guard

758
00:35:22,789 --> 00:35:28,119
you against well energetic particles

759
00:35:26,090 --> 00:35:30,829
which come from solar flares which are

760
00:35:28,119 --> 00:35:32,179
can cause radiation damage to creatures

761
00:35:30,829 --> 00:35:35,929
but even a few meters of water

762
00:35:32,179 --> 00:35:39,289
protection from those also so life on an

763
00:35:35,929 --> 00:35:41,839
M star is not hard to evolve it may be

764
00:35:39,289 --> 00:35:43,519
turtle like the probably creatures this

765
00:35:41,840 --> 00:35:44,480
cannon a moment's notice jump in the

766
00:35:43,519 --> 00:35:47,570
ocean for a while

767
00:35:44,480 --> 00:35:52,490
but that's all it takes to live a long

768
00:35:47,570 --> 00:35:56,260
healthy and happy life on M star so what

769
00:35:52,489 --> 00:35:59,469
does that say M stars now appear to be

770

00:35:56,260 --> 00:36:02,420
in the habitable zone and habitable

771
00:35:59,469 --> 00:36:05,480
there's one other object I want to

772
00:36:02,420 --> 00:36:09,530
mention to you which is probably

773
00:36:05,480 --> 00:36:11,990
habitable and it's a very strange object

774
00:36:09,530 --> 00:36:14,150
in that we know that it exists but we

775
00:36:11,989 --> 00:36:18,829
have never seen one and we may never see

776
00:36:14,150 --> 00:36:20,900
one and these are planets which were

777
00:36:18,829 --> 00:36:23,949
born in the process of the formation of

778
00:36:20,900 --> 00:36:23,950
a planetary system

779
00:36:24,139 --> 00:36:30,619
but in the process had an unfortunate

780
00:36:27,619 --> 00:36:33,319
series of close approaches to other

781
00:36:30,619 --> 00:36:35,630
forming planets with such a geometry

782
00:36:33,320 --> 00:36:38,059
that the mutual gravitational force

783
00:36:35,630 --> 00:36:39,680
accelerated the planets that will always

784
00:36:38,059 --> 00:36:41,570

happen when they pass close to one

785

00:36:39,679 --> 00:36:44,029

another again it's very simple

786

00:36:41,570 --> 00:36:45,650

astrophysics it's Newton's third law for

787

00:36:44,030 --> 00:36:48,800

either every action there's an equal and

788

00:36:45,650 --> 00:36:51,680

opposite reaction and when two planets

789

00:36:48,800 --> 00:36:54,380

pass close to one another put exert the

790

00:36:51,679 --> 00:36:56,179

same force on each other one the planet

791

00:36:54,380 --> 00:36:58,610

will get to speed it up and the other

792

00:36:56,179 --> 00:37:00,349

will be slowed down and if you get

793

00:36:58,610 --> 00:37:03,440

speeded up two or three times in a row

794

00:37:00,349 --> 00:37:05,079

you can achieve escape velocity and

795

00:37:03,440 --> 00:37:08,869

actually be thrown out of the system

796

00:37:05,079 --> 00:37:10,519

what we see in the planetary system we

797

00:37:08,869 --> 00:37:13,429

discovered is that this probably happens

798

00:37:10,519 --> 00:37:14,690

every time in fact when the solar system

799
00:37:13,429 --> 00:37:16,279
was formed there was probably a couple

800
00:37:14,690 --> 00:37:18,769
of planets form that are no longer in

801
00:37:16,280 --> 00:37:20,240
the system they were thrown out one of

802
00:37:18,769 --> 00:37:21,679
them didn't get thrown out it collided

803
00:37:20,239 --> 00:37:23,809
with another one and made what we call

804
00:37:21,679 --> 00:37:26,659
the asteroid belt so we see the evidence

805
00:37:23,809 --> 00:37:30,170
of these sort of mutual accelerations

806
00:37:26,659 --> 00:37:33,170
and the eventual destruction or ejection

807
00:37:30,170 --> 00:37:35,420
which come from them but perhaps one

808
00:37:33,170 --> 00:37:37,599
planet is thrown out of a system every

809
00:37:35,420 --> 00:37:41,480
time a new planetary system is formed

810
00:37:37,599 --> 00:37:44,059
and the result is we get planets that

811
00:37:41,480 --> 00:37:47,559
have no star they are moving freely

812
00:37:44,059 --> 00:37:51,139
through space through the galaxy forever

813
00:37:47,559 --> 00:37:52,639
sort of a daunting thought this is an

814
00:37:51,139 --> 00:37:55,429
artist's conception of one of these a

815
00:37:52,639 --> 00:37:56,629
very new planet because you can see its

816
00:37:55,429 --> 00:37:59,089
star in the background

817
00:37:56,630 --> 00:38:01,990
the upper-right and it's still full of

818
00:37:59,090 --> 00:38:08,030
volcanic activity because it is so young

819
00:38:01,989 --> 00:38:10,279
and we call these nomads or robes or

820
00:38:08,030 --> 00:38:12,050
Wanderers the astronomers have not

821
00:38:10,280 --> 00:38:13,120
really arrived at an official name for

822
00:38:12,050 --> 00:38:15,440
them yet

823
00:38:13,119 --> 00:38:17,389
so there may be as many of these as

824
00:38:15,440 --> 00:38:19,730
there are stars in the Milky Way in the

825
00:38:17,389 --> 00:38:22,009
Milky Way and you might ask why haven't

826
00:38:19,730 --> 00:38:25,369
we seen one well if you work out the

827

00:38:22,010 --> 00:38:28,040
statistics in the whole history of

828
00:38:25,369 --> 00:38:30,349
mankind none of these should have ever

829
00:38:28,039 --> 00:38:32,210
have passed through the solar system if

830
00:38:30,349 --> 00:38:33,889
one did it would have been seen by the

831
00:38:32,210 --> 00:38:37,010
observers and there were good observers

832
00:38:33,889 --> 00:38:38,359
throughout recorded history but it has

833
00:38:37,010 --> 00:38:40,970
never happened and if you work out the

834
00:38:38,360 --> 00:38:43,910
statistics again it's very surprising it

835
00:38:40,969 --> 00:38:45,980
should happen only very very rarely and

836
00:38:43,909 --> 00:38:47,690
with almost any star it will never

837
00:38:45,980 --> 00:38:52,510
happen in the whole history of the star

838
00:38:47,690 --> 00:38:55,400
but they are out there and the

839
00:38:52,510 --> 00:38:57,710
astrophysicists Dave Stephenson at

840
00:38:55,400 --> 00:39:00,170
Caltech has worked out what how these

841
00:38:57,710 --> 00:39:03,110

will evolve and what happens is these

842

00:39:00,170 --> 00:39:05,780

should develop a massive atmospheres

843

00:39:03,110 --> 00:39:08,570

about like Venus and this will actually

844

00:39:05,780 --> 00:39:11,450

keep these such that the surface is warm

845

00:39:08,570 --> 00:39:14,059

enough to support life four times of

846

00:39:11,449 --> 00:39:16,969

billions of years even though there is

847

00:39:14,059 --> 00:39:20,840

no star light no sunlight available to

848

00:39:16,969 --> 00:39:23,209

warm them so these two may be potential

849

00:39:20,840 --> 00:39:25,160

abodes of life it's hard to imagine

850

00:39:23,210 --> 00:39:29,210

intelligent life on a place like this

851

00:39:25,159 --> 00:39:31,159

but life yes and this is going to be one

852

00:39:29,210 --> 00:39:33,470

of the great challenges to astronomy in

853

00:39:31,159 --> 00:39:35,719

the future let's actually find one of

854

00:39:33,469 --> 00:39:37,659

these they have to be there and see what

855

00:39:35,719 --> 00:39:41,739

they're really like

856
00:39:37,659 --> 00:39:41,739
so when we put this all together

857
00:39:41,889 --> 00:39:47,460
we realized that our diagram of where

858
00:39:44,739 --> 00:39:51,099
the habitable zone is really extends

859
00:39:47,460 --> 00:39:53,889
outwards because of the warming effects

860
00:39:51,099 --> 00:40:01,449
of atmospheres insulating layers of gas

861
00:39:53,889 --> 00:40:03,759
and water ice and even beyond solar

862
00:40:01,449 --> 00:40:06,549
system itself if we take into account

863
00:40:03,760 --> 00:40:08,530
the rogue planets and this means that

864
00:40:06,550 --> 00:40:11,289
the number of places where life could

865
00:40:08,530 --> 00:40:16,660
occur is very much greater than we used

866
00:40:11,289 --> 00:40:19,630
to imagine well will there be life the

867
00:40:16,659 --> 00:40:21,579
experiments in our chemical labs have

868
00:40:19,630 --> 00:40:25,300
shown many chemical pathways to the

869
00:40:21,579 --> 00:40:27,699
origin of life all of them use simple

870
00:40:25,300 --> 00:40:29,710
molecules which are known to be present

871
00:40:27,699 --> 00:40:31,799
in the interstellar gas and the material

872
00:40:29,710 --> 00:40:35,949
that makes planets in great abundance

873
00:40:31,800 --> 00:40:38,560
and so it seems very it's inevitable

874
00:40:35,949 --> 00:40:41,099
that almost every habitable planet will

875
00:40:38,559 --> 00:40:43,389
have life on it

876
00:40:41,099 --> 00:40:46,239
that seems one of the things we know

877
00:40:43,389 --> 00:40:49,750
even though we've not ik seen a second

878
00:40:46,239 --> 00:40:52,779
origin yet directly what about

879
00:40:49,750 --> 00:40:56,559
intelligence near the glass is a little

880
00:40:52,780 --> 00:40:58,480
mercury we know it took 4 billion years

881
00:40:56,559 --> 00:41:02,469
to evolve an intelligent species

882
00:40:58,480 --> 00:41:04,960
ourselves and some people argue that

883
00:41:02,469 --> 00:41:08,559
there are in fact some blockades away

884

00:41:04,960 --> 00:41:11,530
choke points that keep intelligence from

885
00:41:08,559 --> 00:41:15,210
developing on the other hand the fossil

886
00:41:11,530 --> 00:41:18,330
record seems to show if all animals

887
00:41:15,210 --> 00:41:20,789
to greater intelligence as time goes on

888
00:41:18,329 --> 00:41:23,069
they're all headed towards becoming

889
00:41:20,789 --> 00:41:25,650
intelligent just given them enough time

890
00:41:23,070 --> 00:41:27,690
and they will make it in our case in the

891
00:41:25,650 --> 00:41:30,180
case of Earth one there's always one

892
00:41:27,690 --> 00:41:33,150
that makes it first in that case it was

893
00:41:30,179 --> 00:41:34,679
us and we should not be surprised to

894
00:41:33,150 --> 00:41:37,519
look around and find out we're the only

895
00:41:34,679 --> 00:41:40,409
intelligent species this does not

896
00:41:37,519 --> 00:41:44,730
indicate as some paleontologists have

897
00:41:40,409 --> 00:41:46,920
claimed to show that intelligent life is

898
00:41:44,730 --> 00:41:49,650

a very rare phenomenon that you only

899

00:41:46,920 --> 00:41:52,380

have one species after four billion

900

00:41:49,650 --> 00:41:55,530

years if we waited another billion years

901

00:41:52,380 --> 00:41:57,269

we might have many more appear for

902

00:41:55,530 --> 00:42:02,070

instance here is one that actually was

903

00:41:57,269 --> 00:42:04,199

ahead of us this is a model of a extinct

904

00:42:02,070 --> 00:42:07,680

dinosaurs name was steno NICUs or cynic

905

00:42:04,199 --> 00:42:09,809

Alice it stood about our height weight

906

00:42:07,679 --> 00:42:12,809

about the same as we do it had binocular

907

00:42:09,809 --> 00:42:15,029

vision designed to replace or see as we

908

00:42:12,809 --> 00:42:18,960

do it could grasp things with its

909

00:42:15,030 --> 00:42:21,090

forepaws was very much like us in fact

910

00:42:18,960 --> 00:42:24,240

this one had a much larger brain than

911

00:42:21,090 --> 00:42:28,680

most dinosaurs most dinosaurs this size

912

00:42:24,239 --> 00:42:30,569

this was a 50 kilogram dinosaur did have

913
00:42:28,679 --> 00:42:34,199
tiny brains the size of a pea they were

914
00:42:30,570 --> 00:42:36,300
really dumb folks but this one had a

915
00:42:34,199 --> 00:42:38,969
brain whose mass was approaching that of

916
00:42:36,300 --> 00:42:41,580
a human infant and it's thought that if

917
00:42:38,969 --> 00:42:44,309
this one had had another few million

918
00:42:41,579 --> 00:42:46,889
years to evolve it might have gone from

919
00:42:44,309 --> 00:42:48,960
this version to what you see in the

920
00:42:46,889 --> 00:42:52,440
foreground here there's the ancestor in

921
00:42:48,960 --> 00:42:57,389
the background an upright primate form

922
00:42:52,440 --> 00:42:58,800
of reptile with a intelligent brain this

923
00:42:57,389 --> 00:43:01,319
could have been the first intelligent

924
00:42:58,800 --> 00:43:03,590
life on Earth and it might have looked

925
00:43:01,320 --> 00:43:09,420
like this and this is a model made by

926
00:43:03,590 --> 00:43:11,130
paleontologists not-not-not speculators

927
00:43:09,420 --> 00:43:14,010
not science fiction writers but by

928
00:43:11,130 --> 00:43:16,730
actual paleontologists who have a sense

929
00:43:14,010 --> 00:43:18,810
of how things evolved this time goes on

930
00:43:16,730 --> 00:43:21,360
well this one didn't get a chance to

931
00:43:18,809 --> 00:43:25,049
make it because 65 million years ago

932
00:43:21,360 --> 00:43:27,360
this happened the ten kilometer asteroid

933
00:43:25,050 --> 00:43:31,640
hit the earth going 20 kilometres a

934
00:43:27,360 --> 00:43:34,170
second created an enormous explosion

935
00:43:31,639 --> 00:43:37,949
which filled the skies of Earth with

936
00:43:34,170 --> 00:43:40,200
dust and also with hot embers which fell

937
00:43:37,949 --> 00:43:42,149
all over the earth after executing

938
00:43:40,199 --> 00:43:45,019
orbits halfway around the earth in some

939
00:43:42,150 --> 00:43:47,960
cases and set the whole earth on fire

940
00:43:45,019 --> 00:43:51,929
this is the Great Firewall on its way

941

00:43:47,960 --> 00:43:55,380
and they said here's what a mad dinosaur

942
00:43:51,929 --> 00:43:59,719
looks like this one's really upset at

943
00:43:55,380 --> 00:44:03,000
this fireball that's headed for it the

944
00:43:59,719 --> 00:44:05,129
entire Earth caught fire at that time

945
00:44:03,000 --> 00:44:07,250
and then the pall of dust caused the

946
00:44:05,130 --> 00:44:09,840
temperatures to plummet plummet on earth

947
00:44:07,250 --> 00:44:12,119
causing all of it all the vegetation to

948
00:44:09,840 --> 00:44:13,740
die the food chain was broken and at

949
00:44:12,119 --> 00:44:15,449
that time all the large creatures

950
00:44:13,739 --> 00:44:18,149
including the large dinosaurs perished

951
00:44:15,449 --> 00:44:21,119
on the earth few of survived and became

952
00:44:18,150 --> 00:44:24,450
our birds of today and in fact what

953
00:44:21,119 --> 00:44:27,269
happened here was we did not evolve an

954
00:44:24,449 --> 00:44:31,109
intelligent dinosaur that was cut off by

955
00:44:27,269 --> 00:44:33,090

this event and when this dust had

956

00:44:31,110 --> 00:44:35,519
finally settled and the fires had

957

00:44:33,090 --> 00:44:37,620
stopped burning the creatures who had

958

00:44:35,519 --> 00:44:40,019
survived all this by hiding in caves and

959

00:44:37,619 --> 00:44:41,759
under rocks came crawling out and

960

00:44:40,019 --> 00:44:45,449
finally found they had the earth all to

961

00:44:41,760 --> 00:44:48,300
themselves and they are us folks the

962

00:44:45,449 --> 00:44:50,429
primitive mammals of that time creatures

963

00:44:48,300 --> 00:44:53,490
a which were about the size of rats and

964

00:44:50,429 --> 00:44:54,179
mice rodents they made it through the

965

00:44:53,489 --> 00:44:57,719
long night

966

00:44:54,179 --> 00:45:01,319
and in time 65 in many years later they

967

00:44:57,719 --> 00:45:04,169
became us what this says I think is that

968

00:45:01,320 --> 00:45:07,170
evolution is inevitable everywhere are

969

00:45:04,170 --> 00:45:08,880
we know that much for sure but more than

970
00:45:07,170 --> 00:45:15,210
that that probably the evolution of

971
00:45:08,880 --> 00:45:18,349
intelligence is inevitable so if you put

972
00:45:15,210 --> 00:45:21,480
all the things I just said together it

973
00:45:18,349 --> 00:45:23,880
says that maybe once a year in our

974
00:45:21,480 --> 00:45:26,760
galaxy a new intelligent technology

975
00:45:23,880 --> 00:45:29,039
using creature peers and by the way I

976
00:45:26,760 --> 00:45:30,540
want your intelligence it's only in the

977
00:45:29,039 --> 00:45:32,039
case of the earth that was just a blink

978
00:45:30,539 --> 00:45:34,529
in cosmic time before technology

979
00:45:32,039 --> 00:45:36,119
developed so that it seems to be

980
00:45:34,530 --> 00:45:38,220
something that's inevitable once you

981
00:45:36,119 --> 00:45:41,819
have intelligence and the ability to use

982
00:45:38,219 --> 00:45:44,189
tools you may need fire by the way

983
00:45:41,820 --> 00:45:45,510
because to make really useful tools that

984
00:45:44,190 --> 00:45:47,760
will do things that you can detect

985
00:45:45,510 --> 00:45:50,550
across the space the distances we

986
00:45:47,760 --> 00:45:56,010
separate the stars you need metals and

987
00:45:50,550 --> 00:45:58,230
you need to be able to form metals into

988
00:45:56,010 --> 00:46:01,890
various things and that just feels like

989
00:45:58,230 --> 00:46:04,610
we you need fire to do all of that but

990
00:46:01,889 --> 00:46:07,409
what does always say they're far more

991
00:46:04,610 --> 00:46:10,320
habitable planets and probably inhabited

992
00:46:07,409 --> 00:46:12,960
planets then we imagine only a few years

993
00:46:10,320 --> 00:46:15,900
ago we should search for signals from

994
00:46:12,960 --> 00:46:18,059
all the stellar types that where the

995
00:46:15,900 --> 00:46:20,670
star lives long enough to evolve an

996
00:46:18,059 --> 00:46:23,009
intelligent species we should be of

997
00:46:20,670 --> 00:46:25,800
emphasis to M stars you're no longer

998

00:46:23,010 --> 00:46:27,630
ruled out in fact it's best to search

999
00:46:25,800 --> 00:46:29,910
for most stars are in the beam of your

1000
00:46:27,630 --> 00:46:32,430
telescope at once you're the plane of

1001
00:46:29,909 --> 00:46:34,859
our Milky Way galaxy and don't even

1002
00:46:32,429 --> 00:46:36,629
avoid observations of empty space

1003
00:46:34,860 --> 00:46:39,480
because those rogue planets are out

1004
00:46:36,630 --> 00:46:40,920
there and although it seems improbable

1005
00:46:39,480 --> 00:46:43,740
that there would be intelligent

1006
00:46:40,920 --> 00:46:47,909
technology using creatures there again

1007
00:46:43,739 --> 00:46:52,079
life is so adaptive and so innovative it

1008
00:46:47,909 --> 00:46:53,909
just might be well we can put numbers in

1009
00:46:52,079 --> 00:46:56,900
all the things I've been describing to

1010
00:46:53,909 --> 00:46:59,279
you and if we do one can make an

1011
00:46:56,900 --> 00:47:02,430
informed guess but it's no better than a

1012
00:46:59,280 --> 00:47:04,470

guess that there might be 10,000 or of

1013

00:47:02,429 --> 00:47:07,889

that order civilizations out there using

1014

00:47:04,469 --> 00:47:11,159

a technology we can detect how shall we

1015

00:47:07,889 --> 00:47:13,089

find them should we look for the lights

1016

00:47:11,159 --> 00:47:15,759

of their cities at night

1017

00:47:13,090 --> 00:47:18,250

this is a this is a mosaic of pictures

1018

00:47:15,760 --> 00:47:19,750

of the earth at night and what you see

1019

00:47:18,250 --> 00:47:23,849

here are the lights of the cities of

1020

00:47:19,750 --> 00:47:26,679

Earth and you can easily spot all the

1021

00:47:23,849 --> 00:47:27,400

main parts of Europe Paris is easy to

1022

00:47:26,679 --> 00:47:31,509

spot

1023

00:47:27,400 --> 00:47:36,550

Berlin is right there you can all find

1024

00:47:31,510 --> 00:47:38,590

it and so it goes you can trace the

1025

00:47:36,550 --> 00:47:42,490

trans-siberian railway across here

1026

00:47:38,590 --> 00:47:44,079

because building the railroad was and

1027
00:47:42,489 --> 00:47:45,759
what was built first and then the cities

1028
00:47:44,079 --> 00:47:48,719
were added later so they are like beads

1029
00:47:45,760 --> 00:47:54,370
on a string across the tractor either

1030
00:47:48,719 --> 00:47:58,179
the flat off stockman well is this what

1031
00:47:54,369 --> 00:47:59,949
we should search for it turns out the

1032
00:47:58,179 --> 00:48:02,949
detect these to detect these lights

1033
00:47:59,949 --> 00:48:05,349
requires a telescope probably at least a

1034
00:48:02,949 --> 00:48:08,649
kilometer in size and maybe five

1035
00:48:05,349 --> 00:48:11,319
kilometers velor building big telescopes

1036
00:48:08,650 --> 00:48:13,809
here including right here at the at the

1037
00:48:11,320 --> 00:48:17,080
at the Astrophysical Institute in

1038
00:48:13,809 --> 00:48:20,380
Potsdam but they're not they're not a

1039
00:48:17,079 --> 00:48:23,469
kilometer in size yet and that's not in

1040
00:48:20,380 --> 00:48:25,750
our near future for sure so this is not

1041
00:48:23,469 --> 00:48:31,299
what we search for what else might

1042
00:48:25,750 --> 00:48:34,969
research for much thought has been given

1043
00:48:31,300 --> 00:48:37,280
to this over the last 50 years and

1044
00:48:34,969 --> 00:48:39,289
when you think about what is but a

1045
00:48:37,280 --> 00:48:41,420
detectable signal must be in the way of

1046
00:48:39,289 --> 00:48:45,108
power or what powers were created and

1047
00:48:41,420 --> 00:48:49,000
required to create it how much will it

1048
00:48:45,108 --> 00:48:52,639
cost you to detect it it turns out that

1049
00:48:49,000 --> 00:48:54,739
the thing that is most appealing always

1050
00:48:52,639 --> 00:48:58,098
has been still is is the search for

1051
00:48:54,739 --> 00:49:01,250
radio signals radio signals and what we

1052
00:48:58,099 --> 00:49:04,220
call the microwave band now why is that

1053
00:49:01,250 --> 00:49:07,690
it's because we live in a universe which

1054
00:49:04,219 --> 00:49:11,719
has in it sources of radio emission

1055

00:49:07,690 --> 00:49:14,720
radio noise which in a way jam our radio

1056
00:49:11,719 --> 00:49:16,969
telescopes and make it so that a signal

1057
00:49:14,719 --> 00:49:19,629
must be more than a certain strength if

1058
00:49:16,969 --> 00:49:23,358
you were to be able to detect it and

1059
00:49:19,630 --> 00:49:28,430
that noise which is called cosmic radio

1060
00:49:23,358 --> 00:49:32,960
noise is least bright at the frequencies

1061
00:49:28,429 --> 00:49:34,578
we call microwaves and we know this and

1062
00:49:32,960 --> 00:49:36,530
we exploit it without really thinking

1063
00:49:34,579 --> 00:49:38,480
about it those frequencies are used to

1064
00:49:36,530 --> 00:49:39,980
communicate with spacecraft they are

1065
00:49:38,480 --> 00:49:42,500
used in the systems that send

1066
00:49:39,980 --> 00:49:44,599
televisions to people's homes and it's

1067
00:49:42,500 --> 00:49:46,489
all because the radio receivers are

1068
00:49:44,599 --> 00:49:48,980
looking at a darkest sky so they can

1069
00:49:46,489 --> 00:49:52,519

little dishes can be the smallest

1070

00:49:48,980 --> 00:49:54,139

possible size and still work and you can

1071

00:49:52,519 --> 00:49:57,079

send signals reliably with the least

1072

00:49:54,139 --> 00:49:59,389

expenditure and power we know this the

1073

00:49:57,079 --> 00:50:01,730

extraterrestrials will know it and they

1074

00:49:59,389 --> 00:50:06,309

will undoubtedly exploit this band of

1075

00:50:01,730 --> 00:50:09,710

frequencies just as we do and so in for

1076

00:50:06,309 --> 00:50:13,190

49 years now we have been searching for

1077

00:50:09,710 --> 00:50:15,300

microwave radio signals the first search

1078

00:50:13,190 --> 00:50:17,679

in which

1079

00:50:15,300 --> 00:50:20,769

dr. Strauss Meyer mentioned was the

1080

00:50:17,679 --> 00:50:23,739

project in 1960 which occurred not in

1081

00:50:20,769 --> 00:50:26,889

the state of Virginia has advertised but

1082

00:50:23,739 --> 00:50:28,949

West Virginia now what that may seem

1083

00:50:26,889 --> 00:50:31,629

like a trivial trivial distance to you

1084
00:50:28,949 --> 00:50:34,568
difference to you but if you were in

1085
00:50:31,630 --> 00:50:38,230
West Virginia you would be deeply

1086
00:50:34,568 --> 00:50:39,789
offended by his statement the dr.

1087
00:50:38,230 --> 00:50:41,710
Strauss might have made in the

1088
00:50:39,789 --> 00:50:44,920
introduction because the West Virginians

1089
00:50:41,710 --> 00:50:47,550
consider themselves greatly superior to

1090
00:50:44,920 --> 00:50:50,170
the peasants if you will of Virginia

1091
00:50:47,550 --> 00:50:53,318
this is the telescope that was used it's

1092
00:50:50,170 --> 00:50:55,180
a 25 meter telescope still in use by the

1093
00:50:53,318 --> 00:50:56,769
way it's a very good telescope these

1094
00:50:55,179 --> 00:51:01,299
were the people that did research in

1095
00:50:56,769 --> 00:51:03,608
réunion we had some years ago it was

1096
00:51:01,300 --> 00:51:06,130
used with what was then a newly invented

1097
00:51:03,608 --> 00:51:09,009
very sensitive radio receiver today we

1098
00:51:06,130 --> 00:51:11,050
have much better ones still but at the

1099
00:51:09,010 --> 00:51:14,800
time the search made sense because you

1100
00:51:11,050 --> 00:51:18,280
could compute with great accuracy how

1101
00:51:14,800 --> 00:51:20,200
far a antenna this size coupled to that

1102
00:51:18,280 --> 00:51:21,849
receiver could detect the strongest

1103
00:51:20,199 --> 00:51:23,739
transmissions we were then making from

1104
00:51:21,849 --> 00:51:26,260
Earth and it turned out to be the

1105
00:51:23,739 --> 00:51:28,358
distance to the nearest stars we had

1106
00:51:26,260 --> 00:51:31,180
crossed a threshold where for the first

1107
00:51:28,358 --> 00:51:33,848
time we could detect other civilizations

1108
00:51:31,179 --> 00:51:36,250
by detecting their own technology

1109
00:51:33,849 --> 00:51:39,010
without requiring them to be a super

1110
00:51:36,250 --> 00:51:42,039
civilization or something like that all

1111
00:51:39,010 --> 00:51:43,359
they had to be was to be like us and it

1112

00:51:42,039 --> 00:51:44,980
was a fair enough assumption that

1113
00:51:43,358 --> 00:51:47,710
duplicates of us probably exist

1114
00:51:44,980 --> 00:51:51,130
somewhere and a project like this could

1115
00:51:47,710 --> 00:51:52,960
succeed in fact at the time we did this

1116
00:51:51,130 --> 00:51:54,999
for all we knew every star in the sky

1117
00:51:52,960 --> 00:51:57,608
had planets radiating this was going to

1118
00:51:54,998 --> 00:52:00,009
be a very easy thing well it turned out

1119
00:51:57,608 --> 00:52:03,068
it hasn't been an easy thing there's

1120
00:52:00,009 --> 00:52:05,920
been many many searches since and so far

1121
00:52:03,068 --> 00:52:09,038
no signal of extraterrestrial origin has

1122
00:52:05,920 --> 00:52:13,028
ever been found in this case the

1123
00:52:09,039 --> 00:52:15,819
so-called Project Ozma we searched for

1124
00:52:13,028 --> 00:52:18,369
signals from the two nearest stars which

1125
00:52:15,818 --> 00:52:20,889
are single and like our Sun it stars

1126
00:52:18,369 --> 00:52:23,920

toss SETI in episode aridity which are

1127

00:52:20,889 --> 00:52:25,748

both 10 light-years from us we could

1128

00:52:23,920 --> 00:52:26,579

have detected our strongest signals from

1129

00:52:25,748 --> 00:52:30,328

those stars

1130

00:52:26,579 --> 00:52:32,680

we could only measure a few frequencies

1131

00:52:30,329 --> 00:52:34,509

because at that time our radio receivers

1132

00:52:32,679 --> 00:52:37,328

could only monitor one frequency at a

1133

00:52:34,509 --> 00:52:40,179

time so we spent two months tuning the

1134

00:52:37,329 --> 00:52:43,298

man if you will looking for signals and

1135

00:52:40,179 --> 00:52:46,210

we didn't find any well this was the

1136

00:52:43,298 --> 00:52:48,670

first and made other people recognize

1137

00:52:46,210 --> 00:52:50,619

that this was in fact a reasonable thing

1138

00:52:48,670 --> 00:52:53,798

scientifically it was supported by hard

1139

00:52:50,619 --> 00:52:56,318

data not by imagining or were philosophy

1140

00:52:53,798 --> 00:52:58,259

and since since that time there have

1141
00:52:56,318 --> 00:53:03,099
been about a 100 similar searches

1142
00:52:58,259 --> 00:53:06,849
searching primarily for radiation radio

1143
00:53:03,099 --> 00:53:09,670
transmissions in the microwave region

1144
00:53:06,849 --> 00:53:12,489
particularly in a frequency band that's

1145
00:53:09,670 --> 00:53:16,210
near that the basic radio frequency of

1146
00:53:12,489 --> 00:53:18,099
the hydrogen atom we now have this is

1147
00:53:16,210 --> 00:53:20,170
the equipment that was used in that

1148
00:53:18,099 --> 00:53:21,940
search just to show you four racks of

1149
00:53:20,170 --> 00:53:25,798
equipment all the monitor one channel

1150
00:53:21,940 --> 00:53:25,798
those of you who were old enough

1151
00:53:26,019 --> 00:53:34,579
amateur is part of the system this

1152
00:53:30,130 --> 00:53:35,900
system was all vacuum tools some of you

1153
00:53:34,579 --> 00:53:37,969
have probably never heard of such a

1154
00:53:35,900 --> 00:53:40,639
thing but it was before there were

1155
00:53:37,969 --> 00:53:43,699
transistors it was also before there

1156
00:53:40,639 --> 00:53:45,259
were computers and believe it or not

1157
00:53:43,699 --> 00:53:46,848
there was a time in the history of the

1158
00:53:45,260 --> 00:53:50,090
earth when there were no computers no

1159
00:53:46,849 --> 00:53:52,160
that's a surprise to the young people

1160
00:53:50,090 --> 00:53:53,930
here but it was true in the data was

1161
00:53:52,159 --> 00:53:56,449
regarded of the fanatic recorder which

1162
00:53:53,929 --> 00:53:58,098
was right here and just in case we

1163
00:53:56,449 --> 00:54:01,279
actually heard something we had this

1164
00:53:58,099 --> 00:54:03,080
device here some of the old timers were

1165
00:54:01,280 --> 00:54:06,260
recognized as a woollen sack tape

1166
00:54:03,079 --> 00:54:08,299
recorder which was all set up to record

1167
00:54:06,260 --> 00:54:10,430
the voices of the extraterrestrials

1168
00:54:08,300 --> 00:54:12,769
should we have happened on a channel

1169

00:54:10,429 --> 00:54:16,549
that had voices in it which didn't

1170
00:54:12,769 --> 00:54:18,949
happen unfortunately well it's been 48

1171
00:54:16,550 --> 00:54:21,609
years we've moved on to much larger

1172
00:54:18,949 --> 00:54:23,569
telescopes this one is routinely

1173
00:54:21,608 --> 00:54:26,509
searching for extraterrestrial

1174
00:54:23,570 --> 00:54:28,550
intelligence signals through the program

1175
00:54:26,510 --> 00:54:31,820
called SETI at home which I think

1176
00:54:28,550 --> 00:54:34,490
probably some of you work with it's a

1177
00:54:31,820 --> 00:54:37,250
way you can search for signals on your

1178
00:54:34,489 --> 00:54:38,838
own home computer if you join SETI at

1179
00:54:37,250 --> 00:54:41,179
home which is free they send you a free

1180
00:54:38,838 --> 00:54:42,829
software and then when you ask them they

1181
00:54:41,179 --> 00:54:44,629
send you what they call a work packet

1182
00:54:42,829 --> 00:54:46,130
which is a set of data from the Arecibo

1183
00:54:44,630 --> 00:54:50,269

radio telescope which is what this is

1184

00:54:46,130 --> 00:54:52,010

and your computer processes it and sends

1185

00:54:50,269 --> 00:54:54,800

information back to the site at home

1186

00:54:52,010 --> 00:54:55,820

headquarters and it just could be that

1187

00:54:54,800 --> 00:54:57,670

you could

1188

00:54:55,820 --> 00:55:00,559

be the one to make the detection the

1189

00:54:57,670 --> 00:55:03,470

finding of a signal from another world

1190

00:55:00,559 --> 00:55:05,289

it hasn't happened yet they're presently

1191

00:55:03,469 --> 00:55:07,909

about two hundred thousand people

1192

00:55:05,289 --> 00:55:11,719

cooperating in this effort it has been a

1193

00:55:07,909 --> 00:55:13,639

very great success case of distributed

1194

00:55:11,719 --> 00:55:18,259

computing it's established a whole genre

1195

00:55:13,639 --> 00:55:22,789

of computing in which shared computers

1196

00:55:18,260 --> 00:55:25,850

are used free of charge typically to do

1197

00:55:22,789 --> 00:55:31,039

enormous and calculations is being used

1198
00:55:25,849 --> 00:55:33,170
with the genome research with studies of

1199
00:55:31,039 --> 00:55:35,900
possible protein folding different

1200
00:55:33,170 --> 00:55:39,619
things like that in any case this is the

1201
00:55:35,900 --> 00:55:46,160
world's largest radio telescope it's 300

1202
00:55:39,619 --> 00:55:49,309
meters in diameter this structure up

1203
00:55:46,159 --> 00:55:52,369
here is 100 meters across it's the size

1204
00:55:49,309 --> 00:55:54,259
of the next largest telescope there two

1205
00:55:52,369 --> 00:55:58,000
next largest telescopes with the same

1206
00:55:54,260 --> 00:55:58,000
size most 100 meters one their bond

1207
00:55:58,329 --> 00:56:03,579
Ethel's burger and a new one that said

1208
00:56:01,630 --> 00:56:04,989
to read back West Virginia were the

1209
00:56:03,579 --> 00:56:09,429
first search happened

1210
00:56:04,989 --> 00:56:11,170
in this case the area which captures the

1211
00:56:09,429 --> 00:56:14,289
radio signals is suspended from these

1212
00:56:11,170 --> 00:56:17,619
three towers usually used at about 150

1213
00:56:14,289 --> 00:56:21,369
meters high is suspended structure here

1214
00:56:17,619 --> 00:56:26,619
weighs over a thousand metric tons and

1215
00:56:21,369 --> 00:56:29,199
it has 2nd of June no I'm here which has

1216
00:56:26,619 --> 00:56:32,199
entered a 20 meter radio trying to

1217
00:56:29,199 --> 00:56:34,539
reflector another smaller reflector to

1218
00:56:32,199 --> 00:56:38,349
bring the radiation captured by the big

1219
00:56:34,539 --> 00:56:40,569
dish to a very sharp focus this is a

1220
00:56:38,349 --> 00:56:43,059
closer of a picture of it one other

1221
00:56:40,568 --> 00:56:46,420
thing about this is that in it there is

1222
00:56:43,059 --> 00:56:48,189
a 1 megawatt power radio transmitter

1223
00:56:46,420 --> 00:56:50,588
which is used for radar studies such as

1224
00:56:48,188 --> 00:56:54,670
the ones who determine the rotation rate

1225
00:56:50,588 --> 00:56:56,978
of mercury and that one megawatt signal

1226

00:56:54,670 --> 00:57:00,429
when focused into a narrow beam by the

1227
00:56:56,978 --> 00:57:02,169
big reflector creates such a power level

1228
00:57:00,429 --> 00:57:04,059
that's duplicated without the big

1229
00:57:02,170 --> 00:57:07,119
reflector would require you to transmit

1230
00:57:04,059 --> 00:57:08,380
20 million million watts which is 20

1231
00:57:07,119 --> 00:57:11,469
times the total electric power

1232
00:57:08,380 --> 00:57:13,689
production of the earth very strong

1233
00:57:11,469 --> 00:57:15,338
signal it can be detected by a similar

1234
00:57:13,688 --> 00:57:18,009
instrument anywhere in the Milky Way

1235
00:57:15,338 --> 00:57:20,199
bout the galaxy even at a distance of a

1236
00:57:18,009 --> 00:57:22,748
hundred thousand light-years this signal

1237
00:57:20,199 --> 00:57:26,108
can be detected and this is what the

1238
00:57:22,748 --> 00:57:30,458
reflector surface looks like it's very

1239
00:57:26,108 --> 00:57:34,598
large it consists of 38,000 panels each

1240
00:57:30,458 --> 00:57:35,879

about the size of a typical dining-room

1241

00:57:34,599 --> 00:57:38,730
table

1242

00:57:35,880 --> 00:57:41,099
all put in position to an accuracy of

1243

00:57:38,730 --> 00:57:43,048
one millimeter in order to give high

1244

00:57:41,099 --> 00:57:48,930
efficiency to the receiving of power of

1245

00:57:43,048 --> 00:57:50,818
the telescope now in recent years we've

1246

00:57:48,929 --> 00:57:53,669
recognized that something we had ignored

1247

00:57:50,818 --> 00:57:57,750
shouldn't be ignored any longer and that

1248

00:57:53,670 --> 00:57:59,519
is the possibility that signals are

1249

00:57:57,750 --> 00:58:02,699
coming from extraterrestrials not just

1250

00:57:59,518 --> 00:58:05,788
by radio or by radio but perhaps on

1251

00:58:02,699 --> 00:58:08,009
light waves after all we had dismissed

1252

00:58:05,789 --> 00:58:10,500
light waves earlier because the lasers

1253

00:58:08,009 --> 00:58:12,900
we had couldn't be detected even at the

1254

00:58:10,500 --> 00:58:15,989
distance of the nearest star and also

1255
00:58:12,900 --> 00:58:17,430
the noise associated with photons is

1256
00:58:15,989 --> 00:58:20,639
much greater than the noise associated

1257
00:58:17,429 --> 00:58:22,469
with radio photons and so for many years

1258
00:58:20,639 --> 00:58:25,348
we thought it was a waste of time to

1259
00:58:22,469 --> 00:58:28,679
search for optical signals but now that

1260
00:58:25,349 --> 00:58:30,568
has changed it makes sense after all to

1261
00:58:28,679 --> 00:58:33,298
search for optical and infrared signals

1262
00:58:30,568 --> 00:58:37,679
after all what you're looking at here is

1263
00:58:33,298 --> 00:58:39,719
a huge building you can get some idea

1264
00:58:37,679 --> 00:58:42,118
with scale where these cars and also by

1265
00:58:39,719 --> 00:58:43,409
these three whether American football

1266
00:58:42,119 --> 00:58:46,410
fields what they're about the size of a

1267
00:58:43,409 --> 00:58:50,969
soccer field which have been added

1268
00:58:46,409 --> 00:58:52,500
through the magic of computer graphics

1269
00:58:50,969 --> 00:58:53,969
to the roof of this building they're not

1270
00:58:52,500 --> 00:58:56,009
really there they're just put there to

1271
00:58:53,969 --> 00:59:00,179
give you a feel for the scale of this

1272
00:58:56,009 --> 00:59:02,309
building but what is this building it's

1273
00:59:00,179 --> 00:59:05,098
not intended to signal extraterrestrials

1274
00:59:02,309 --> 00:59:09,089
but it has in it some technology which

1275
00:59:05,099 --> 00:59:11,490
makes it feasible and reasonable that

1276
00:59:09,088 --> 00:59:15,509
there be interstellar communication by

1277
00:59:11,489 --> 00:59:18,739
way of lasers this building is what is

1278
00:59:15,509 --> 00:59:20,539
called the National Ignition facility

1279
00:59:18,739 --> 00:59:22,969
the order was what's this ignition

1280
00:59:20,539 --> 00:59:25,880
what's it getting and United what this

1281
00:59:22,969 --> 00:59:28,279
is is one of the major experiments in a

1282
00:59:25,880 --> 00:59:31,460
attempting to find a way to achieve

1283

00:59:28,280 --> 00:59:33,950
control nuclear fusion of hydrogen into

1284
00:59:31,460 --> 00:59:36,349
helium as happens in the stars to

1285
00:59:33,949 --> 00:59:39,949
provide a clean and abundant source of

1286
00:59:36,349 --> 00:59:42,349
energy other experiments like this all

1287
00:59:39,949 --> 00:59:43,879
over the world are all massive they're

1288
00:59:42,349 --> 00:59:45,710
very expensive

1289
00:59:43,880 --> 00:59:48,470
this one's been costing several hundred

1290
00:59:45,710 --> 00:59:51,409
US dollars a year and it's been going on

1291
00:59:48,469 --> 00:59:53,149
for about 15 years and it is finally

1292
00:59:51,409 --> 00:59:54,710
nearing the point any day now actually

1293
00:59:53,150 --> 00:59:57,108
literally any day now they're ready to

1294
00:59:54,710 --> 00:59:58,550
try it the first time you know whole

1295
00:59:57,108 --> 01:00:02,869
building may blow up if this really

1296
00:59:58,550 --> 01:00:06,160
works well but it's time to try it this

1297
01:00:02,869 --> 01:00:11,780

particular one takes the approach of

1298

01:00:06,159 --> 01:00:14,059

trying to heat a small glass container

1299

01:00:11,780 --> 01:00:16,910

about five millimeters in diameter 5

1300

01:00:14,059 --> 01:00:20,420

millimeters tiny which is filled with a

1301

01:00:16,909 --> 01:00:24,858

mix of isotopes of hydrogen hydrogen

1302

01:00:20,420 --> 01:00:28,099

deuterium and tritium and what we know

1303

01:00:24,858 --> 01:00:30,710

is because it happens in the Sun is that

1304

01:00:28,099 --> 01:00:33,980

if that mix is heated to a temperature

1305

01:00:30,710 --> 01:00:36,740

of more than a billion degrees nuclear

1306

01:00:33,980 --> 01:00:39,320

fusion will occur and you'll get convert

1307

01:00:36,739 --> 01:00:41,239

hydrogen to helium actually producing

1308

01:00:39,320 --> 01:00:44,809

much more energy per unit mass than we

1309

01:00:41,239 --> 01:00:46,639

get from our fission nuclear reactors so

1310

01:00:44,809 --> 01:00:50,079

this is a game to make that happen well

1311

01:00:46,639 --> 01:00:52,699

how do you do that you have to heat the

1312
01:00:50,079 --> 01:00:54,049
gases to billions of degrees and as you

1313
01:00:52,699 --> 01:00:55,730
can sense as you do that the pressure

1314
01:00:54,050 --> 01:00:57,710
gets really high all things going to

1315
01:00:55,730 --> 01:01:00,050
explode before it ever gets to billion

1316
01:00:57,710 --> 01:01:04,170
degrees and the only way to get around

1317
01:01:00,050 --> 01:01:06,510
that is to heat it so fast that the

1318
01:01:04,170 --> 01:01:08,309
the walls of this glass container just

1319
01:01:06,510 --> 01:01:11,580
through inertia will keep the gas

1320
01:01:08,309 --> 01:01:14,099
confined long enough that the nuclear

1321
01:01:11,579 --> 01:01:18,269
fusion will occur before the whole thing

1322
01:01:14,099 --> 01:01:20,130
explodes now long enough means less than

1323
01:01:18,269 --> 01:01:22,889
a billionth of a second less than a

1324
01:01:20,130 --> 01:01:24,809
nanosecond so what you have to do is to

1325
01:01:22,889 --> 01:01:27,179
dump enough energy into this little tiny

1326
01:01:24,809 --> 01:01:30,539
pellet in less than a billionth of a

1327
01:01:27,179 --> 01:01:34,500
second such that the temperature gets to

1328
01:01:30,539 --> 01:01:36,210
over a billion degrees and at which

1329
01:01:34,500 --> 01:01:38,670
point it doesn't matter everything's

1330
01:01:36,210 --> 01:01:40,730
going to fuse when you have to achieve

1331
01:01:38,670 --> 01:01:42,990
that before the whole thing explodes

1332
01:01:40,730 --> 01:01:45,300
well how do you do that you can't just

1333
01:01:42,989 --> 01:01:47,849
put a blowtorch to it or something like

1334
01:01:45,300 --> 01:01:52,620
that the way they're doing this here is

1335
01:01:47,849 --> 01:01:55,889
to zap pebble with a very powerful laser

1336
01:01:52,619 --> 01:01:59,069
and let the laser light heat the the

1337
01:01:55,889 --> 01:02:01,789
gases in the little glass pebble but it

1338
01:01:59,070 --> 01:02:07,289
takes an enormous amount of laser light

1339
01:02:01,789 --> 01:02:10,289
in fact this shows you the lasers

1340

01:02:07,289 --> 01:02:12,929
actually only half of the lasers which

1341
01:02:10,289 --> 01:02:15,449
are used to ignite the hydrogen ignite

1342
01:02:12,929 --> 01:02:18,480
in the sense of nuclear fusion and a

1343
01:02:15,449 --> 01:02:20,480
pebble if you will well the little glass

1344
01:02:18,480 --> 01:02:25,250
sphere at 500 millimeters in diameter

1345
01:02:20,480 --> 01:02:29,769
each one of these tubes you see here is

1346
01:02:25,250 --> 01:02:31,780
part of a very powerful laser

1347
01:02:29,769 --> 01:02:35,940
lasers which have been developed and I

1348
01:02:31,780 --> 01:02:38,619
work quite well which when they flash

1349
01:02:35,940 --> 01:02:42,460
produce a flash of light which has a

1350
01:02:38,619 --> 01:02:44,980
power of 10 to the 15th power watts

1351
01:02:42,460 --> 01:02:48,250
it's a petawatt some of you will have

1352
01:02:44,980 --> 01:02:52,059
learned a new word today petawatt it's a

1353
01:02:48,250 --> 01:02:53,710
word in German - 10 to the 15th watts

1354
01:02:52,059 --> 01:02:54,969

which is a thousand times the total

1355

01:02:53,710 --> 01:02:58,000

electric power production of the earth

1356

01:02:54,969 --> 01:02:59,949

comes out of one of these things but it

1357

01:02:58,000 --> 01:03:01,750

lasts about a nanosecond about a

1358

01:02:59,949 --> 01:03:04,449

billionth of a second actually what

1359

01:03:01,750 --> 01:03:08,409

latest versions produced all this light

1360

01:03:04,449 --> 01:03:11,500

in 100 nanoseconds it takes a hundred

1361

01:03:08,409 --> 01:03:15,039

and ninety two of these to raise the

1362

01:03:11,500 --> 01:03:17,050

temperature in the little glass d2 the

1363

01:03:15,039 --> 01:03:19,329

temperature required for nuclear fusion

1364

01:03:17,050 --> 01:03:20,950

so this is one bank there's actually the

1365

01:03:19,329 --> 01:03:23,289

second planet in the background you can

1366

01:03:20,949 --> 01:03:25,750

see in Europe and in the center is a

1367

01:03:23,289 --> 01:03:28,989

device with lots of optics and mirrors

1368

01:03:25,750 --> 01:03:33,460

and things which focuses all 92b beams

1369
01:03:28,989 --> 01:03:39,149
on this little tiny target area and what

1370
01:03:33,460 --> 01:03:42,400
is there this is it it's a little metal

1371
01:03:39,150 --> 01:03:44,470
cylinder inside which the glass the

1372
01:03:42,400 --> 01:03:46,119
glass level is you can see it's about

1373
01:03:44,469 --> 01:03:48,939
the size of the people of the human eye

1374
01:03:46,119 --> 01:03:50,710
and half the lasers are shooting the

1375
01:03:48,940 --> 01:03:55,030
light in one side the other

1376
01:03:50,710 --> 01:03:56,980
and the other side and there are

1377
01:03:55,030 --> 01:03:59,619
internal reflections of such such as all

1378
01:03:56,980 --> 01:04:02,619
of the energy and the light ends up in

1379
01:03:59,619 --> 01:04:05,950
the little glass sphere and so if all

1380
01:04:02,619 --> 01:04:08,019
the optics work properly and the beams

1381
01:04:05,949 --> 01:04:11,259
are properly focused so that they all

1382
01:04:08,019 --> 01:04:13,300
land on the sphere it's been calculated

1383
01:04:11,260 --> 01:04:15,849
that this will result in ignition and

1384
01:04:13,300 --> 01:04:17,410
nuclear fusion as I've said they have

1385
01:04:15,849 --> 01:04:19,269
finished now all of the construction

1386
01:04:17,409 --> 01:04:20,649
alignment of this thing and any day now

1387
01:04:19,269 --> 01:04:23,380
they're going to try this for the first

1388
01:04:20,650 --> 01:04:26,200
time well that's an interesting story in

1389
01:04:23,380 --> 01:04:29,050
itself but it's of interest to us

1390
01:04:26,199 --> 01:04:31,509
because these lasers exist and if you

1391
01:04:29,050 --> 01:04:34,060
take such a laser and focus it's being

1392
01:04:31,510 --> 01:04:36,580
with a 10 meter telescope into a narrow

1393
01:04:34,059 --> 01:04:39,190
beam like that which comes out of a

1394
01:04:36,579 --> 01:04:44,190
radio telescope and we have many 10

1395
01:04:39,190 --> 01:04:47,400
meter dishes or 10 meter class dishes

1396
01:04:44,190 --> 01:04:51,760
European Southern Observatory has them

1397

01:04:47,400 --> 01:04:54,519
many other countries have them now the

1398
01:04:51,760 --> 01:04:56,980
beam that comes out is very narrow and

1399
01:04:54,519 --> 01:04:59,588
in fact it is so bright that it will

1400
01:04:56,980 --> 01:05:02,260
outshine its star if it's on the planet

1401
01:04:59,588 --> 01:05:03,690
of a star and not by a little bit by

1402
01:05:02,260 --> 01:05:07,810
about a thousand times

1403
01:05:03,690 --> 01:05:09,579
so if extraterrestrials want to signal

1404
01:05:07,809 --> 01:05:12,670
other civilizations I'll notice they

1405
01:05:09,579 --> 01:05:14,799
they'll have to want to do this they can

1406
01:05:12,670 --> 01:05:18,190
take one of these systems and create

1407
01:05:14,800 --> 01:05:20,050
flashes of light which are visible all

1408
01:05:18,190 --> 01:05:23,289
the way across the galaxy if you will if

1409
01:05:20,050 --> 01:05:24,730
dust isn't in the way and you don't even

1410
01:05:23,289 --> 01:05:26,679
need to know the wavelength when I say

1411
01:05:24,730 --> 01:05:29,019

they outshine the star they outshine the

1412

01:05:26,679 --> 01:05:30,460

star at all wavelengths so you don't

1413

01:05:29,019 --> 01:05:31,469

even need filters you don't need to know

1414

01:05:30,460 --> 01:05:35,460

what the wave

1415

01:05:31,469 --> 01:05:37,949

- the light is it will work and other

1416

01:05:35,460 --> 01:05:41,519

places of course are trying to make the

1417

01:05:37,949 --> 01:05:43,949

same thing well that says this just

1418

01:05:41,519 --> 01:05:46,849

could be happening there's one very

1419

01:05:43,949 --> 01:05:49,710

improbable side to it and that is that

1420

01:05:46,849 --> 01:05:52,409

preachers have to be wanting to signal

1421

01:05:49,710 --> 01:05:53,760

they have to aim this thing at you they

1422

01:05:52,409 --> 01:05:55,889

have to know the existence of your

1423

01:05:53,760 --> 01:05:58,230

planet they have to aim the beam at you

1424

01:05:55,889 --> 01:06:01,440

so it's not like in the radio where you

1425

01:05:58,230 --> 01:06:03,119

can eavesdrop on other people's radio

1426
01:06:01,440 --> 01:06:05,789
transmissions in this case they have to

1427
01:06:03,119 --> 01:06:07,559
be intentionally signalling so perhaps

1428
01:06:05,789 --> 01:06:09,509
that makes it improbable but on the

1429
01:06:07,559 --> 01:06:11,940
other hand it is very inexpensive to

1430
01:06:09,510 --> 01:06:13,650
build detection systems in fact our eyes

1431
01:06:11,940 --> 01:06:15,990
could see these flashes if we could

1432
01:06:13,650 --> 01:06:18,180
respond to a flashlight that lasted a

1433
01:06:15,989 --> 01:06:20,099
billionth of a second unfortunately we

1434
01:06:18,179 --> 01:06:21,719
can it's too bad we could all sit up in

1435
01:06:20,099 --> 01:06:24,179
the yard and chair and look at the night

1436
01:06:21,719 --> 01:06:28,529
sky and eventually we'd say flash then

1437
01:06:24,179 --> 01:06:30,299
you get our Nobel Prize you know what a

1438
01:06:28,530 --> 01:06:32,310
wonderful situation unfortunately our

1439
01:06:30,300 --> 01:06:37,550
eyes don't have nanosecond time

1440
01:06:32,309 --> 01:06:37,549
responses push that

1441
01:06:41,630 --> 01:06:48,608
but it is easy to build simple

1442
01:06:43,789 --> 01:06:50,569
instruments this is one our group built

1443
01:06:48,608 --> 01:06:53,980
has been used at the Lick Observatory

1444
01:06:50,568 --> 01:06:57,980
and University California for about

1445
01:06:53,980 --> 01:07:00,318
almost eight years now in fact was built

1446
01:06:57,980 --> 01:07:03,289
by a young students

1447
01:07:00,318 --> 01:07:05,659
senior thesis and it uses a 1 meter

1448
01:07:03,289 --> 01:07:08,359
telescope that was not much used so it's

1449
01:07:05,659 --> 01:07:10,818
all very inexpensive and this device is

1450
01:07:08,358 --> 01:07:13,489
itself very inexpensive it only cost a

1451
01:07:10,818 --> 01:07:15,199
few thousand dollars to build and yet

1452
01:07:13,489 --> 01:07:18,258
it's quite capable of detecting the

1453
01:07:15,199 --> 01:07:21,018
flashes from stars very far away of the

1454

01:07:18,259 --> 01:07:23,778
kind I just described to you it uses a

1455
01:07:21,018 --> 01:07:26,778
very unusual but interesting technique

1456
01:07:23,778 --> 01:07:28,730
for detecting signals which is different

1457
01:07:26,778 --> 01:07:31,250
from the way we detect signals with any

1458
01:07:28,730 --> 01:07:33,019
other device and I think this will be of

1459
01:07:31,250 --> 01:07:37,278
interest to any of you who are in the

1460
01:07:33,018 --> 01:07:39,858
signal detection business here what's in

1461
01:07:37,278 --> 01:07:43,179
this box you're looking at here this is

1462
01:07:39,858 --> 01:07:43,179
the Box seen close up

1463
01:07:43,570 --> 01:07:47,590
actually the light comes in a hole and

1464
01:07:46,059 --> 01:07:50,529
the bottom here goes in here

1465
01:07:47,590 --> 01:07:53,079
and there are a bunch of mirrors in

1466
01:07:50,530 --> 01:07:54,519
there this shows you the inside that box

1467
01:07:53,079 --> 01:07:56,619
is where the light comes in through the

1468
01:07:54,519 --> 01:07:59,110

telescope goes in here the light is

1469

01:07:56,619 --> 01:07:59,829

split on a mirror so that 1/3 of it goes

1470

01:07:59,110 --> 01:08:02,950

this way

1471

01:07:59,829 --> 01:08:04,360

the other 2/3 go this way and down here

1472

01:08:02,949 --> 01:08:06,129

there's a mirror which splits that light

1473

01:08:04,360 --> 01:08:07,599

so it ends up with 1/3 of light going

1474

01:08:06,130 --> 01:08:10,360

this way therefore the light this way

1475

01:08:07,599 --> 01:08:12,429

and at the end of each of those tubes is

1476

01:08:10,360 --> 01:08:14,650

a photomultiplier tube of a very great

1477

01:08:12,429 --> 01:08:17,619

sensitivity and fast time response man a

1478

01:08:14,650 --> 01:08:19,779

second time response those are easy to

1479

01:08:17,619 --> 01:08:23,858

come by they've been built particularly

1480

01:08:19,779 --> 01:08:26,439

for use in nuclear energy experiments so

1481

01:08:23,859 --> 01:08:29,920

this is a case where astrophysics is

1482

01:08:26,439 --> 01:08:32,019

helping us and so what we have is star

1483
01:08:29,920 --> 01:08:34,779
light coming in and the B divided by log

1484
01:08:32,020 --> 01:08:38,220
3 paths and out of each of these comes a

1485
01:08:34,779 --> 01:08:39,670
cable and whenever the photon is

1486
01:08:38,220 --> 01:08:41,380
intercepted by one of the

1487
01:08:39,670 --> 01:08:44,020
photomultiplier tubes a pulse comes out

1488
01:08:41,380 --> 01:08:46,210
of that cable now why are we doing all

1489
01:08:44,020 --> 01:08:49,150
this why don't we just put all the light

1490
01:08:46,210 --> 01:08:50,980
into one detector it's because if you

1491
01:08:49,149 --> 01:08:54,129
put it all into one detector you get

1492
01:08:50,979 --> 01:08:56,649
what we call false positives you get

1493
01:08:54,130 --> 01:08:59,289
some flashes and your pulses of

1494
01:08:56,649 --> 01:09:01,479
electricity out because cosmic rays hit

1495
01:08:59,289 --> 01:09:04,298
the detector or there's a radioactive

1496
01:09:01,479 --> 01:09:07,079
decay in the glass of the

1497
01:09:04,298 --> 01:09:09,548
photomultiplier which triggers it or

1498
01:09:07,079 --> 01:09:12,779
there's a Corona discharge these things

1499
01:09:09,548 --> 01:09:15,069
use high voltage and the end result is

1500
01:09:12,779 --> 01:09:16,750
if you have only one detector and the

1501
01:09:15,069 --> 01:09:18,220
first ones built had that you got false

1502
01:09:16,750 --> 01:09:19,689
positives all the time and you never

1503
01:09:18,220 --> 01:09:22,659
know which was the real signal and which

1504
01:09:19,689 --> 01:09:23,960
was something coming from space in this

1505
01:09:22,659 --> 01:09:26,029
case you

1506
01:09:23,960 --> 01:09:28,909
the false positives because the light is

1507
01:09:26,029 --> 01:09:31,969
split in three ways goes through three

1508
01:09:28,909 --> 01:09:34,909
detectors and then the signals out of

1509
01:09:31,970 --> 01:09:37,789
these three cables are compared in a

1510
01:09:34,909 --> 01:09:40,250
coincidence detector which looks for the

1511

01:09:37,789 --> 01:09:43,399
coincident time points and reveal of

1512
01:09:40,250 --> 01:09:48,350
several photons so if three photons

1513
01:09:43,399 --> 01:09:51,859
arrive at once you win so in one channel

1514
01:09:48,350 --> 01:09:54,950
the photons are coming along almost all

1515
01:09:51,859 --> 01:09:57,109
of them from the star second channel

1516
01:09:54,949 --> 01:09:59,689
therefore photons coming in random times

1517
01:09:57,109 --> 01:10:01,309
third channel of added times but if

1518
01:09:59,689 --> 01:10:04,099
there's a laser flash you're going to

1519
01:10:01,310 --> 01:10:06,680
find that all three channels of a photon

1520
01:10:04,100 --> 01:10:09,440
which is synchronized and your constants

1521
01:10:06,680 --> 01:10:12,860
detector detects this and it turns out

1522
01:10:09,439 --> 01:10:14,719
that with the photon rates we have that

1523
01:10:12,859 --> 01:10:19,789
we should get a false positive

1524
01:10:14,720 --> 01:10:21,260
where just by coincidence three photons

1525
01:10:19,789 --> 01:10:22,939

from the star arrive at the same time

1526

01:10:21,260 --> 01:10:25,880

only about once a year which has been

1527

01:10:22,939 --> 01:10:27,559

our experience with 2-foot with two

1528

01:10:25,880 --> 01:10:29,779

channels you get a false alarm at least

1529

01:10:27,560 --> 01:10:33,560

once a day and what we're dealing here

1530

01:10:29,779 --> 01:10:36,800

with here is costs own statistics the

1531

01:10:33,560 --> 01:10:39,110

statistics describe the timing of the

1532

01:10:36,800 --> 01:10:41,600

arrival of photons in a system like this

1533

01:10:39,109 --> 01:10:44,899

or how things are distributed when you

1534

01:10:41,600 --> 01:10:46,850

throw salt on a cup of table top in this

1535

01:10:44,899 --> 01:10:49,369

case we're not looking for an increase

1536

01:10:46,850 --> 01:10:51,680

in light intensity we're looking in

1537

01:10:49,369 --> 01:10:53,449

looking for a deviation in the

1538

01:10:51,680 --> 01:10:56,990

statistical arrival times

1539

01:10:53,449 --> 01:10:59,929

photons from what is predicted by the

1540
01:10:56,989 --> 01:11:02,599
poisson law a whole new approach is

1541
01:10:59,930 --> 01:11:04,400
acting weak signals in fact you win with

1542
01:11:02,600 --> 01:11:05,679
only three photons it's about the fate

1543
01:11:04,399 --> 01:11:06,998
of signal you can pass

1544
01:11:05,679 --> 01:11:09,309
imagine and yet you've been getting a

1545
01:11:06,998 --> 01:11:10,988
conclusive positive result from three

1546
01:11:09,309 --> 01:11:13,869
protons from the fact that they all

1547
01:11:10,988 --> 01:11:15,819
arrive at the same time it's been a very

1548
01:11:13,868 --> 01:11:18,609
successful we've had one false alarm in

1549
01:11:15,819 --> 01:11:22,840
eight years which isn't what we should

1550
01:11:18,609 --> 01:11:24,759
have but so far no true positives but we

1551
01:11:22,840 --> 01:11:27,369
will keep searching them and other

1552
01:11:24,760 --> 01:11:30,039
people are searching this is easy to do

1553
01:11:27,368 --> 01:11:32,558
this is a new setup at Harvard

1554
01:11:30,038 --> 01:11:36,069
University where they have one and a one

1555
01:11:32,559 --> 01:11:40,659
and a half metre spherical antenna with

1556
01:11:36,069 --> 01:11:43,448
and they have 64 multiplier tubes this

1557
01:11:40,658 --> 01:11:45,848
shows you looking into the telescope and

1558
01:11:43,448 --> 01:11:48,759
here's the whole thing this is the main

1559
01:11:45,849 --> 01:11:51,819
air down here and up here there's a

1560
01:11:48,760 --> 01:11:54,998
mirror here which reflects the light out

1561
01:11:51,819 --> 01:11:57,219
to 64 detectors which aren't here in

1562
01:11:54,998 --> 01:11:59,679
this picture and this is being used

1563
01:11:57,219 --> 01:12:03,760
every night that the skies are clear to

1564
01:11:59,679 --> 01:12:08,019
search for optical pulses now what about

1565
01:12:03,760 --> 01:12:12,550
the radio let's go back to that one of

1566
01:12:08,019 --> 01:12:16,559
the most major projects in SETI is one

1567
01:12:12,550 --> 01:12:19,860
to build as dedicated telescope to serve

1568

01:12:16,559 --> 01:12:23,260
radio SETI searches microwave searches

1569
01:12:19,859 --> 01:12:25,509
and we need this because historically

1570
01:12:23,260 --> 01:12:28,530
we've always had to observe as guest

1571
01:12:25,510 --> 01:12:31,570
observers on other people's telescopes

1572
01:12:28,529 --> 01:12:33,399
yet we need a great deal of observing

1573
01:12:31,569 --> 01:12:35,698
time because we must search perhaps

1574
01:12:33,399 --> 01:12:39,129
millions of stars before we will succeed

1575
01:12:35,698 --> 01:12:40,868
you accept the 10,000 stars might have

1576
01:12:39,130 --> 01:12:43,239
civilizations it means only 1 in 10

1577
01:12:40,868 --> 01:12:44,708
million stars has one so you have to

1578
01:12:43,238 --> 01:12:47,228
look at 10 million stars before you even

1579
01:12:44,708 --> 01:12:49,210
have a small chance of success and that

1580
01:12:47,229 --> 01:12:52,400
calls for a great deal of observe

1581
01:12:49,210 --> 01:12:54,859
and even at Arecibo when we could point

1582
01:12:52,399 --> 01:12:57,909

the telescope we could only get it the

1583

01:12:54,859 --> 01:13:00,799

best about 20 days a year of observation

1584

01:12:57,909 --> 01:13:04,099

and so some years now it's 10 years ago

1585

01:13:00,800 --> 01:13:07,730

and we at the SETI Institute decided to

1586

01:13:04,100 --> 01:13:11,270

build a new system to search for radio

1587

01:13:07,729 --> 01:13:14,779

signals and build it in a way which was

1588

01:13:11,270 --> 01:13:16,850

very inexpensive and that is to instead

1589

01:13:14,779 --> 01:13:20,539

of building a single very large

1590

01:13:16,850 --> 01:13:22,310

telescope it was a large number of very

1591

01:13:20,539 --> 01:13:24,560

small dishes and connected together

1592

01:13:22,310 --> 01:13:26,870

through commute computer technology so

1593

01:13:24,560 --> 01:13:30,320

that they duplicate the performance of a

1594

01:13:26,869 --> 01:13:32,090

very large telescope like Arecibo and

1595

01:13:30,319 --> 01:13:34,099

that's what the Allen telescope array is

1596

01:13:32,090 --> 01:13:36,800

it's a big radio telescope made from

1597
01:13:34,100 --> 01:13:38,510
small pieces doing it this way saves

1598
01:13:36,800 --> 01:13:42,680
money because the cost of radio

1599
01:13:38,510 --> 01:13:45,710
telescopes does not go linearly in

1600
01:13:42,680 --> 01:13:48,020
proportion to the collecting area of the

1601
01:13:45,710 --> 01:13:49,699
telescope the bigger you make it the

1602
01:13:48,020 --> 01:13:52,400
more it costs per square meter of

1603
01:13:49,699 --> 01:13:54,800
collecting area so if you use many small

1604
01:13:52,399 --> 01:13:56,809
antennas the total cost of collecting

1605
01:13:54,800 --> 01:13:58,820
area is very small you do have to pay a

1606
01:13:56,810 --> 01:14:01,520
price on the computer electronics to

1607
01:13:58,819 --> 01:14:04,189
make everything work right but if you

1608
01:14:01,520 --> 01:14:07,280
optimize the distribution or the size of

1609
01:14:04,189 --> 01:14:09,799
telescope and the cost of connecting the

1610
01:14:07,279 --> 01:14:12,738
dishes together you can say perhaps 50

1611
01:14:09,800 --> 01:14:15,860
percent or more in achieving a collector

1612
01:14:12,738 --> 01:14:20,059
area of any size you can imagine and so

1613
01:14:15,859 --> 01:14:21,799
this project is in progress now it's a

1614
01:14:20,060 --> 01:14:23,390
joint partnership between the SETI

1615
01:14:21,800 --> 01:14:24,680
Institute and the radio astronomy

1616
01:14:23,390 --> 01:14:29,360
laboratory at University of California

1617
01:14:24,680 --> 01:14:32,690
at Berkeley and this shows you

1618
01:14:29,359 --> 01:14:35,179
some of the dishes in the manufacturing

1619
01:14:32,689 --> 01:14:38,210
plant which is in Idaho quite a long

1620
01:14:35,180 --> 01:14:40,010
ways from the observatory and these are

1621
01:14:38,210 --> 01:14:41,239
the dishes they're each six meter dishes

1622
01:14:40,010 --> 01:14:43,369
and they're made by a very special

1623
01:14:41,239 --> 01:14:45,590
process in which a sheet of aluminium is

1624
01:14:43,369 --> 01:14:47,869
pressed to the right shape by putting a

1625

01:14:45,590 --> 01:14:49,550
huge bladder of water on top of it to

1626
01:14:47,869 --> 01:14:53,029
just press it down by brute force

1627
01:14:49,550 --> 01:14:56,150
against a mold and this shows one of the

1628
01:14:53,029 --> 01:14:59,029
finished reflectors of course it takes

1629
01:14:56,149 --> 01:15:01,609
more than that it takes back up the

1630
01:14:59,029 --> 01:15:04,550
structures things to strengthen it the

1631
01:15:01,609 --> 01:15:07,429
reflectors has to be shipped from the

1632
01:15:04,550 --> 01:15:09,170
manufacturing plant in Idaho to the

1633
01:15:07,430 --> 01:15:12,740
observatory which is at Hat Creek

1634
01:15:09,170 --> 01:15:15,829
California very tiny town about 20 miles

1635
01:15:12,739 --> 01:15:18,649
north of the volcano mount a lot less

1636
01:15:15,829 --> 01:15:23,659
and in Northern California the dishes

1637
01:15:18,649 --> 01:15:25,849
are so large that being you have to tilt

1638
01:15:23,659 --> 01:15:28,760
them up as you see here in order that

1639
01:15:25,850 --> 01:15:31,910

they don't cause accidents on the

1640

01:15:28,760 --> 01:15:34,789

highway but when you do this they're too

1641

01:15:31,909 --> 01:15:37,069

tall to go to under the under passes and

1642

01:15:34,789 --> 01:15:39,019

so they have to be on this rotating

1643

01:15:37,069 --> 01:15:41,779

mouth so that when you have to go under

1644

01:15:39,020 --> 01:15:43,830

an overpass you can sell these up so

1645

01:15:41,779 --> 01:15:45,389

they're horizontal and they were bought

1646

01:15:43,829 --> 01:15:47,269

overpass and then you put it back this

1647

01:15:45,390 --> 01:15:49,590

way and go on your way

1648

01:15:47,270 --> 01:15:51,990

and there are the police to make sure

1649

01:15:49,590 --> 01:15:55,920

nobody gets hurt and doing this process

1650

01:15:51,989 --> 01:15:58,529

and nobody has so far this is the design

1651

01:15:55,920 --> 01:16:01,619

it's a very clever design

1652

01:15:58,529 --> 01:16:05,699

there's a 6-meter primary it is a

1653

01:16:01,619 --> 01:16:12,029

Gregorian design meaning there is a

1654
01:16:05,699 --> 01:16:15,779
secondary reflector which is beyond the

1655
01:16:12,029 --> 01:16:17,789
focal point of the main reflector which

1656
01:16:15,779 --> 01:16:21,840
turns the radiation around back towards

1657
01:16:17,789 --> 01:16:25,619
the main reflector and in this way you

1658
01:16:21,840 --> 01:16:28,079
can achieve a telescope which is what we

1659
01:16:25,619 --> 01:16:32,819
call unblocked there's nothing blocking

1660
01:16:28,079 --> 01:16:36,630
the path of the Rays coming in here's

1661
01:16:32,819 --> 01:16:38,059
how they come in and you can see the

1662
01:16:36,630 --> 01:16:40,699
path of the Rays the device

1663
01:16:38,060 --> 01:16:43,430
come to the focal point and the whole

1664
01:16:40,699 --> 01:16:45,649
area through which they pass was never

1665
01:16:43,430 --> 01:16:48,020
instructed by anything this allows the

1666
01:16:45,649 --> 01:16:53,839
telescope to be more efficient and also

1667
01:16:48,020 --> 01:17:02,120
to be less noisy now to make this thing

1668
01:16:53,840 --> 01:17:05,239
work you need maybe a focal point

1669
01:17:02,119 --> 01:17:07,220
focal area which is here and it has been

1670
01:17:05,239 --> 01:17:09,229
designed so that it can cover a very

1671
01:17:07,220 --> 01:17:11,840
wide frequency band at any given time

1672
01:17:09,229 --> 01:17:14,719
all the way from half a gigahertz up to

1673
01:17:11,840 --> 01:17:17,989
11 gigahertz gigahertz is a thousand

1674
01:17:14,720 --> 01:17:21,230
megahertz now to do that you need a

1675
01:17:17,989 --> 01:17:25,069
special what we call a feed antennas the

1676
01:17:21,229 --> 01:17:27,799
antenna which captures the radiation and

1677
01:17:25,069 --> 01:17:31,059
this is a picture of it it looks like

1678
01:17:27,800 --> 01:17:35,090
this it's got actually four sets of fins

1679
01:17:31,060 --> 01:17:37,780
removed and monnel annoys amplifier

1680
01:17:35,090 --> 01:17:40,480
meaning we need temperatures for the

1681
01:17:37,779 --> 01:17:42,969
first amplifiers of that

1682

01:17:40,479 --> 01:17:45,759
that of liquid air so the first

1683
01:17:42,970 --> 01:17:48,550
amplifiers are a pla is a low noise

1684
01:17:45,760 --> 01:17:51,480
amplifier and we have a refrigerator

1685
01:17:48,550 --> 01:17:51,480
back here

1686
01:17:51,600 --> 01:17:56,289
closed-circuit refrigerator which

1687
01:17:53,890 --> 01:17:58,000
provides coolant which cools the low

1688
01:17:56,289 --> 01:18:00,880
noise amplifier so that you get room

1689
01:17:58,000 --> 01:18:02,590
temperature all right it's not room

1690
01:18:00,880 --> 01:18:05,440
temperature at 80 degree temperatures at

1691
01:18:02,590 --> 01:18:07,390
the first amplifiers this is standard

1692
01:18:05,439 --> 01:18:10,809
practice in radio telescopes it's just

1693
01:18:07,390 --> 01:18:14,020
hard to do here because the place where

1694
01:18:10,810 --> 01:18:16,840
the signal energy is picked off his way

1695
01:18:14,020 --> 01:18:18,610
up here at this difficult place and this

1696
01:18:16,840 --> 01:18:20,730

requires us to actually put the

1697

01:18:18,609 --> 01:18:24,069
refrigerators and such inside the feed

1698

01:18:20,729 --> 01:18:28,049
which turns out to work much to my

1699

01:18:24,069 --> 01:18:32,170
surprise it does not affect the actual

1700

01:18:28,050 --> 01:18:35,230
electromagnetic performance of the feed

1701

01:18:32,170 --> 01:18:37,859
itself the refrigerator it was a big

1702

01:18:35,229 --> 01:18:40,000
problem when these were being built

1703

01:18:37,859 --> 01:18:41,789
nobody made such a small refrigerator

1704

01:18:40,000 --> 01:18:46,810
but they do now

1705

01:18:41,789 --> 01:18:49,269
they and they're made in fact for use

1706

01:18:46,810 --> 01:18:51,310
with mobile phones mobile phone towers

1707

01:18:49,270 --> 01:18:53,320
and so what could have been a very

1708

01:18:51,310 --> 01:18:55,810
expensive item is really about the shelf

1709

01:18:53,319 --> 01:19:00,519
made in large quantities no and that's

1710

01:18:55,810 --> 01:19:01,989
what's used in these systems telecom

1711
01:19:00,520 --> 01:19:04,520
they come from the telephone

1712
01:19:01,988 --> 01:19:06,779
communication industry

1713
01:19:04,520 --> 01:19:08,580
and there's a little problem we call the

1714
01:19:06,779 --> 01:19:11,519
last millimeter problem because there

1715
01:19:08,579 --> 01:19:14,369
you have a slight a short distance where

1716
01:19:11,520 --> 01:19:15,690
the wiring has to be at room temperature

1717
01:19:14,369 --> 01:19:17,729
or ambient temperature and that

1718
01:19:15,689 --> 01:19:20,579
introduces some noise and there's been a

1719
01:19:17,729 --> 01:19:22,069
great struggle to minimize that and it's

1720
01:19:20,579 --> 01:19:25,309
pretty well solved

1721
01:19:22,069 --> 01:19:28,738
well this shows it under construction

1722
01:19:25,310 --> 01:19:30,120
It's Made in a tent as you see there's

1723
01:19:28,738 --> 01:19:35,159
one of the dishes with the backup

1724
01:19:30,119 --> 01:19:39,329
structure being applied once the dish is

1725
01:19:35,159 --> 01:19:42,420
put together it's lifted by a crane here

1726
01:19:39,329 --> 01:19:44,880
you see it and that crane is mobile and

1727
01:19:42,420 --> 01:19:48,119
it takes the dish out and puts it on a

1728
01:19:44,880 --> 01:19:52,079
pedestal although this takes about one

1729
01:19:48,119 --> 01:19:54,750
day and this is - here are two finished

1730
01:19:52,079 --> 01:19:56,550
dishes and you see the sense of the size

1731
01:19:54,750 --> 01:19:57,988
here and you see that there's some happy

1732
01:19:56,550 --> 01:20:04,039
people because they've put all this

1733
01:19:57,988 --> 01:20:06,599
together these are recent pictures of

1734
01:20:04,039 --> 01:20:10,289
finished district dishes in place and

1735
01:20:06,600 --> 01:20:13,560
the bottom picture is the ATA telescope

1736
01:20:10,289 --> 01:20:16,649
array as it is today with 42 antennas at

1737
01:20:13,560 --> 01:20:19,950
this point the ultimate design calls for

1738
01:20:16,649 --> 01:20:23,509
350 antennas which would give it one

1739

01:20:19,949 --> 01:20:25,679
hectare of collecting area and

1740
01:20:23,510 --> 01:20:27,210
unfortunately right now construction has

1741
01:20:25,680 --> 01:20:28,860
stopped for lack of money but we're

1742
01:20:27,210 --> 01:20:29,460
ready to build more dishes as soon as

1743
01:20:28,859 --> 01:20:33,210
more money

1744
01:20:29,460 --> 01:20:35,250
piers tells you where it is it's not

1745
01:20:33,210 --> 01:20:39,719
very useful there's an aerial view of

1746
01:20:35,250 --> 01:20:42,060
the 88 42 as it's called and you may

1747
01:20:39,719 --> 01:20:44,789
wonder why the dish's intercession is a

1748
01:20:42,060 --> 01:20:46,500
strange arrangement and the radio

1749
01:20:44,789 --> 01:20:48,510
astronomers here will know exactly why

1750
01:20:46,500 --> 01:20:51,439
that is it's because these are used you

1751
01:20:48,510 --> 01:20:54,000
know as method called aperture synthesis

1752
01:20:51,439 --> 01:20:55,919
in which they are laid out in such a way

1753
01:20:54,000 --> 01:20:58,409

that when the signals are combined that

1754

01:20:55,920 --> 01:21:00,390

can give you a very high resolution high

1755

01:20:58,409 --> 01:21:02,670

quality radio image of a piece of the

1756

01:21:00,390 --> 01:21:05,480

sky and it will be used for that in

1757

01:21:02,670 --> 01:21:08,550

addition to searching for SETI signals

1758

01:21:05,479 --> 01:21:10,319

this is what the finished antenna should

1759

01:21:08,550 --> 01:21:12,060

look like and as again you see the

1760

01:21:10,319 --> 01:21:14,309

dishes seem to be spread out almost at

1761

01:21:12,060 --> 01:21:15,989

random but they're not this is all a

1762

01:21:14,310 --> 01:21:18,870

very clever design which gives a very

1763

01:21:15,988 --> 01:21:21,000

high quality image I'm going to show you

1764

01:21:18,869 --> 01:21:21,539

an animation now of what this would look

1765

01:21:21,000 --> 01:21:23,850

like

1766

01:21:21,539 --> 01:21:25,319

unfortunately this animation has gotten

1767

01:21:23,850 --> 01:21:27,600

slightly corrupted I don't know what

1768
01:21:25,319 --> 01:21:29,309
happened but I'll play it anyway anyway

1769
01:21:27,600 --> 01:21:31,230
there's some artifacts you'll see which

1770
01:21:29,310 --> 01:21:38,489
maybe look like signals coming in maybe

1771
01:21:31,229 --> 01:21:42,109
they are what the telescope array would

1772
01:21:38,488 --> 01:21:42,109
look like when it is done

1773
01:21:56,750 --> 01:22:01,359
the first 42 dishes are now in full

1774
01:21:58,850 --> 01:22:04,489
operation everything is working properly

1775
01:22:01,359 --> 01:22:07,189
and they are being used for a SETI

1776
01:22:04,488 --> 01:22:08,869
search of the Galactic plane and they're

1777
01:22:07,189 --> 01:22:10,879
also being used for conventional radio

1778
01:22:08,869 --> 01:22:14,390
astronomy particularly to do pulsar

1779
01:22:10,880 --> 01:22:16,159
observations it's not the biggest there

1780
01:22:14,390 --> 01:22:20,270
won't be the biggest the biggest is

1781
01:22:16,159 --> 01:22:22,760
still Arecibo another big ones include

1782
01:22:20,270 --> 01:22:25,340
the addition bond which unfortunately

1783
01:22:22,760 --> 01:22:28,039
has never been used for SETI work and

1784
01:22:25,340 --> 01:22:28,699
this new dish at Green Bank where it all

1785
01:22:28,039 --> 01:22:34,760
started

1786
01:22:28,698 --> 01:22:37,189
in West Virginia which is also a 100

1787
01:22:34,760 --> 01:22:40,699
meter dish the same size as the antenna

1788
01:22:37,189 --> 01:22:43,488
at Bond and as I said Arecibo is still

1789
01:22:40,698 --> 01:22:45,979
in full operation in 24 hours a day

1790
01:22:43,488 --> 01:22:48,819
collecting SETI data for the city and

1791
01:22:45,979 --> 01:22:51,639
home project so things are looking up

1792
01:22:48,819 --> 01:22:57,109
with regard to our search capabilities

1793
01:22:51,640 --> 01:22:58,910
at the same time there's well at the

1794
01:22:57,109 --> 01:23:01,579
same time that we're still making more

1795
01:22:58,909 --> 01:23:04,550
progress this is the project which just

1796

01:23:01,579 --> 01:23:06,649
was started in Russia they had

1797
01:23:04,550 --> 01:23:07,670
groundbreaking for this project of about

1798
01:23:06,649 --> 01:23:11,929
two months ago

1799
01:23:07,670 --> 01:23:14,270
it's a project to build a radio

1800
01:23:11,930 --> 01:23:17,380
telescope which is modeled and precisely

1801
01:23:14,270 --> 01:23:20,330
on the Arecibo design it's called fast

1802
01:23:17,380 --> 01:23:22,130
which is based on an english name for

1803
01:23:20,329 --> 01:23:25,100
this project which is somewhat strange

1804
01:23:22,130 --> 01:23:28,569
for a Russian project fast stands for

1805
01:23:25,100 --> 01:23:30,829
500 meter aperture spherical telescope

1806
01:23:28,569 --> 01:23:32,869
so it's a spherical telescope like

1807
01:23:30,829 --> 01:23:36,719
Arecibo but instead of being 300 meters

1808
01:23:32,869 --> 01:23:38,460
it will be 500 meters it uses an ad town

1809
01:23:36,719 --> 01:23:42,060
which is not fully in the ground as at

1810
01:23:38,460 --> 01:23:45,569

Arecibo but this rim is up at the above

1811
01:23:42,060 --> 01:23:49,170
the ground this is the actual outline of

1812
01:23:45,569 --> 01:23:49,909
the dish so it's supported by a ring of

1813
01:23:49,170 --> 01:23:53,489
girders

1814
01:23:49,909 --> 01:23:56,698
towers and it has six towers this is

1815
01:23:53,488 --> 01:23:59,309
instead of the three Arecibo plus the

1816
01:23:56,698 --> 01:24:02,069
new twist which is they're making the

1817
01:23:59,310 --> 01:24:05,370
focal point so it's movable so you see

1818
01:24:02,069 --> 01:24:07,259
some winches here under computer control

1819
01:24:05,369 --> 01:24:08,909
are going to move the feet around so as

1820
01:24:07,260 --> 01:24:11,610
to point the telescope at different

1821
01:24:08,909 --> 01:24:13,319
parts of the sky they predict it will

1822
01:24:11,609 --> 01:24:16,589
only take three years to build this

1823
01:24:13,319 --> 01:24:18,599
which I find rather challenging an idea

1824
01:24:16,590 --> 01:24:19,369
this is what it will look like when it's

1825
01:24:18,600 --> 01:24:21,900
finished

1826
01:24:19,369 --> 01:24:23,550
and I'm sorry I'd call this a depression

1827
01:24:21,899 --> 01:24:24,569
this Russian tell us about the Chinese

1828
01:24:23,550 --> 01:24:26,489
telescope

1829
01:24:24,569 --> 01:24:32,299
the Chinese telescope being built in

1830
01:24:26,488 --> 01:24:34,948
southwest China and here you see it with

1831
01:24:32,300 --> 01:24:38,369
your feet apparatus suspended from the

1832
01:24:34,948 --> 01:24:42,359
six dollars as the fast will be you and

1833
01:24:38,369 --> 01:24:44,789
it is completed so there's a great

1834
01:24:42,359 --> 01:24:48,448
future ahead at the same time there are

1835
01:24:44,789 --> 01:24:50,698
a few dark clouds on the horizon we are

1836
01:24:48,448 --> 01:24:54,119
you always used our civilization as a

1837
01:24:50,698 --> 01:24:56,909
benchmark for what might be out there

1838
01:24:54,119 --> 01:24:58,559
transmitting signals to us and those

1839
01:24:56,909 --> 01:25:00,630
signals is our strongest signals are

1840
01:24:58,560 --> 01:25:02,160
like the ones to come from the Empire

1841
01:25:00,630 --> 01:25:06,020
State Building which is what you see

1842
01:25:02,159 --> 01:25:08,599
here these are all the antennas on top

1843
01:25:06,020 --> 01:25:11,310
120 different television stations

1844
01:25:08,600 --> 01:25:15,180
transmitting typically when a megawatt

1845
01:25:11,310 --> 01:25:16,739
each out towards the horizon so that

1846
01:25:15,180 --> 01:25:19,650
most of the power actually goes off in

1847
01:25:16,738 --> 01:25:23,979
space here is the same sort of thing at

1848
01:25:19,649 --> 01:25:25,839
San Francisco this is probably the most

1849
01:25:23,979 --> 01:25:28,539
in the United States the tower that

1850
01:25:25,840 --> 01:25:29,819
transmits the most energy as you can see

1851
01:25:28,539 --> 01:25:35,279
it

1852
01:25:29,819 --> 01:25:37,590
I think it's about 150 meters high it's

1853

01:25:35,279 --> 01:25:41,849
got three antenna masts on the top of it

1854
01:25:37,590 --> 01:25:44,520
and it's got 30 transmitters on it stand

1855
01:25:41,850 --> 01:25:49,800
up until it well today still it is

1856
01:25:44,520 --> 01:25:52,430
transmitting 20 20 mega watts of power

1857
01:25:49,800 --> 01:25:56,310
from the 30 stations that are

1858
01:25:52,430 --> 01:25:58,140
transmitting from 20 mega watts but in

1859
01:25:56,310 --> 01:25:59,610
the United States on June 12th all the

1860
01:25:58,140 --> 01:26:02,850
transmitters are being changed to

1861
01:25:59,609 --> 01:26:05,299
digital transmissions and the power is

1862
01:26:02,850 --> 01:26:07,560
going to go down to 6 mega watts

1863
01:26:05,300 --> 01:26:09,449
well that doesn't sound like a big deal

1864
01:26:07,560 --> 01:26:11,420
but to settle it is because our

1865
01:26:09,449 --> 01:26:14,010
benchmark is suddenly getting fainter

1866
01:26:11,420 --> 01:26:16,159
and it's a result of improving

1867
01:26:14,010 --> 01:26:18,930

technology in the transition to digital

1868

01:26:16,159 --> 01:26:23,159

electronics which allows you to get away

1869

01:26:18,930 --> 01:26:24,740

with lower transmitter power and that's

1870

01:26:23,159 --> 01:26:29,239

what happens in the rest of the world

1871

01:26:24,739 --> 01:26:31,619

well we see it not only happening here

1872

01:26:29,239 --> 01:26:33,329

we see it happening with the military

1873

01:26:31,619 --> 01:26:36,329

radars which are another part of our

1874

01:26:33,329 --> 01:26:38,909

benchmark this is a ballistic early

1875

01:26:36,329 --> 01:26:41,489

warning radar of the United States and

1876

01:26:38,909 --> 01:26:43,439

Alaska I don't know if you can read the

1877

01:26:41,489 --> 01:26:46,319

sign it says Point Barrow which is the

1878

01:26:43,439 --> 01:26:47,879

northernmost point in North America and

1879

01:26:46,319 --> 01:26:49,559

this is a picture I took a few months

1880

01:26:47,880 --> 01:26:50,940

ago I went up there to because I wanted

1881

01:26:49,560 --> 01:26:53,610

to see if that was a good place to do

1882
01:26:50,939 --> 01:26:56,879
SETI and it is except for this radar

1883
01:26:53,609 --> 01:26:58,799
which is transmitting super high power

1884
01:26:56,880 --> 01:27:00,690
all the time

1885
01:26:58,800 --> 01:27:02,070
it was an interesting trip by oh I just

1886
01:27:00,689 --> 01:27:04,559
drove up here he got out and started

1887
01:27:02,069 --> 01:27:07,469
taking pictures and set up my spectrum

1888
01:27:04,560 --> 01:27:11,039
analyzer nobody seemed to care which I

1889
01:27:07,470 --> 01:27:15,390
thought was pretty amazing but I'm gonna

1890
01:27:11,039 --> 01:27:17,369
show you the spectrum I saw and to many

1891
01:27:15,390 --> 01:27:19,740
of you this will be peculiar but this is

1892
01:27:17,369 --> 01:27:22,439
the spectrum seen from the vicinity of

1893
01:27:19,739 --> 01:27:24,269
the that barrel with radar going from

1894
01:27:22,439 --> 01:27:27,389
three hundred megahertz radio frequency

1895
01:27:24,270 --> 01:27:29,640
up to two Peter Curtis and you see one

1896
01:27:27,390 --> 01:27:33,360
peak here that cell phone is mobile

1897
01:27:29,640 --> 01:27:36,000
phone is in Barrow Alaska no other

1898
01:27:33,359 --> 01:27:39,319
transmissions which is good but this is

1899
01:27:36,000 --> 01:27:43,079
the radar and it's as you can see it's

1900
01:27:39,319 --> 01:27:45,439
transmission extends over a range of

1901
01:27:43,079 --> 01:27:47,789
frequencies covering about 50 megahertz

1902
01:27:45,439 --> 01:27:49,349
and if you actually watch this you would

1903
01:27:47,789 --> 01:27:52,710
see the spectrum is changing all the

1904
01:27:49,350 --> 01:27:54,120
time and what's happening here is what

1905
01:27:52,710 --> 01:27:57,539
is known as a spread spectrum

1906
01:27:54,119 --> 01:27:59,340
transmission where the radars jumping

1907
01:27:57,539 --> 01:28:02,069
its frequency around jumping around all

1908
01:27:59,340 --> 01:28:07,319
the time and this is a way to keep it

1909
01:28:02,069 --> 01:28:08,439
from being masked or interfered with

1910

01:28:07,319 --> 01:28:12,429
what I am

1911
01:28:08,439 --> 01:28:13,869
an opposing radar the same approaches

1912
01:28:12,430 --> 01:28:19,810
actually used with cell phones and other

1913
01:28:13,869 --> 01:28:21,069
things and what this says is though that

1914
01:28:19,810 --> 01:28:22,930
even though there's a lot of power

1915
01:28:21,069 --> 01:28:24,429
coming out of this radar it's spread out

1916
01:28:22,930 --> 01:28:28,710
over so much spectrum that it will be

1917
01:28:24,430 --> 01:28:31,539
very hard to detect at great distance

1918
01:28:28,710 --> 01:28:34,449
the last thing I want to show you is the

1919
01:28:31,539 --> 01:28:36,579
other threat to our paradigm for what

1920
01:28:34,449 --> 01:28:38,949
we're searching for and that's the

1921
01:28:36,579 --> 01:28:43,390
satellites which transmit television to

1922
01:28:38,949 --> 01:28:45,699
homes on earth this is a drawing of one

1923
01:28:43,390 --> 01:28:50,890
of them it's an actual satellite known

1924
01:28:45,699 --> 01:28:52,779

as galaxy 11 it transmits power to all

1925

01:28:50,890 --> 01:28:55,800

of North America and most of South

1926

01:28:52,779 --> 01:28:58,619

America using extremely clever beams

1927

01:28:55,800 --> 01:29:01,090

antennas which beam all that radiation

1928

01:28:58,619 --> 01:29:04,390

specifically to the areas where the

1929

01:29:01,090 --> 01:29:05,619

receivers are notice the amount of power

1930

01:29:04,390 --> 01:29:09,220

from

1931

01:29:05,619 --> 01:29:12,239

all these figures these the conc band is

1932

01:29:09,220 --> 01:29:17,460

the television channel demand total

1933

01:29:12,239 --> 01:29:20,109

typical power out as 20 watts

1934

01:29:17,460 --> 01:29:22,090

compare that to the million watts that

1935

01:29:20,109 --> 01:29:25,779

was typical of our old-fashioned

1936

01:29:22,090 --> 01:29:28,539

transmitters some of them are 75 watts

1937

01:29:25,779 --> 01:29:30,579

as you can see but what's happening here

1938

01:29:28,539 --> 01:29:32,880

is that instead of transmitting millions

1939
01:29:30,579 --> 01:29:36,880
of watch to deliver television to homes

1940
01:29:32,880 --> 01:29:39,940
we are sending out 20 watts and all of

1941
01:29:36,880 --> 01:29:41,920
that is being very precisely on the

1942
01:29:39,939 --> 01:29:44,139
earth these are the contours of beam

1943
01:29:41,920 --> 01:29:46,420
intensity and you can see that the power

1944
01:29:44,140 --> 01:29:48,280
is going where the receivers are there's

1945
01:29:46,420 --> 01:29:50,289
even a finger that reaches out to Hawaii

1946
01:29:48,279 --> 01:29:52,779
there's a finger that reaches out to

1947
01:29:50,289 --> 01:29:55,960
clear regrowth and so these are

1948
01:29:52,779 --> 01:29:58,630
extremely ingenious but almost all that

1949
01:29:55,960 --> 01:30:00,399
power is absorbed by the earth the

1950
01:29:58,630 --> 01:30:04,300
actual amount of power going into space

1951
01:30:00,399 --> 01:30:07,029
is about one watt and that means our

1952
01:30:04,300 --> 01:30:11,199
planet is on the way to becoming very

1953
01:30:07,029 --> 01:30:13,869
much quieter much fainter than it has

1954
01:30:11,199 --> 01:30:16,539
been for the last 50 years and that

1955
01:30:13,869 --> 01:30:18,880
worries us very intelligent

1956
01:30:16,539 --> 01:30:21,970
civilizations will do this justice

1957
01:30:18,880 --> 01:30:24,279
because it's efficient saves money but

1958
01:30:21,970 --> 01:30:29,350
also very importantly it allows you to

1959
01:30:24,279 --> 01:30:31,090
share frequencies and as we need to do

1960
01:30:29,350 --> 01:30:34,390
these days because so many people are

1961
01:30:31,090 --> 01:30:36,610
using things such as mobile phones so it

1962
01:30:34,390 --> 01:30:38,820
may be in the end we have to go and

1963
01:30:36,609 --> 01:30:41,859
search for the lights of cities at night

1964
01:30:38,819 --> 01:30:43,960
and watch for these

1965
01:30:41,859 --> 01:30:46,299
they're actually not as bright as you

1966
01:30:43,960 --> 01:30:48,730
see here this photos been enhanced to

1967

01:30:46,300 --> 01:30:52,020
make the cities of the brighter those of

1968
01:30:48,729 --> 01:30:52,019
you are wondering is permitted

1969
01:30:54,590 --> 01:30:59,869
it's this is a more realistic picture

1970
01:30:57,430 --> 01:31:04,940
taken from space of the earth at night

1971
01:30:59,869 --> 01:31:07,220
and as you could get a sense it is going

1972
01:31:04,939 --> 01:31:10,159
to be very hard and take a lot of effort

1973
01:31:07,220 --> 01:31:11,960
to see these lights the one good thing

1974
01:31:10,159 --> 01:31:14,149
about them is they are there and they

1975
01:31:11,960 --> 01:31:17,119
will probably be there for a long long

1976
01:31:14,149 --> 01:31:19,929
time maybe something else will happen to

1977
01:31:17,119 --> 01:31:22,550
help us solar power satellites in space

1978
01:31:19,930 --> 01:31:24,350
maybe there will be colonization of

1979
01:31:22,550 --> 01:31:27,550
space and early to be communication

1980
01:31:24,350 --> 01:31:27,550
links and power links between

1981
01:31:27,819 --> 01:31:32,509

communities in space

1982

01:31:29,539 --> 01:31:34,069

maybe there's a galactic internet which

1983

01:31:32,510 --> 01:31:35,780

requires the use of the high-power

1984

01:31:34,069 --> 01:31:38,809

transmitters to transmit from one

1985

01:31:35,779 --> 01:31:41,929

stellar system to another some wonderful

1986

01:31:38,810 --> 01:31:44,270

fantasy would certainly help us may be

1987

01:31:41,930 --> 01:31:48,200

nice if it were true but maybe it is and

1988

01:31:44,270 --> 01:31:51,200

maybe it isn't so we are making progress

1989

01:31:48,199 --> 01:31:53,949

but there are challenges ahead and

1990

01:31:51,199 --> 01:31:53,949

that's my message