
Sofia Sheikh
Choosing a Maximum Drift Rate in a SETI Search: Astrophysical Considerations

1
00:00:00,240 --> 00:00:10,839
[Music]

2
00:00:16,970 --> 00:00:14,749
hi everyone my name is Sophia and I am a

3
00:00:20,660 --> 00:00:16,980
third year grad student at Penn State

4
00:00:23,960 --> 00:00:20,670
and astronomy in astrobiology and I am

5
00:00:26,900 --> 00:00:23,970
doing my PhD in say which is search for

6
00:00:30,620 --> 00:00:26,910
extraterrestrial intelligence and this

7
00:00:32,930 --> 00:00:30,630
is a pretty uncommon choice SETI has

8
00:00:35,150 --> 00:00:32,940
often had kind of the perception of

9
00:00:38,739 --> 00:00:35,160
being kind of kooky fringe out of the

10
00:00:41,450 --> 00:00:38,749
mainstream and it doesn't actually get

11
00:00:44,810 --> 00:00:41,460
almost any government funding so it's a

12
00:00:46,459 --> 00:00:44,820
difficult discipline to do a PhD in but

13
00:00:48,439 --> 00:00:46,469

I think it's very important and we're

14
00:00:50,509 --> 00:00:48,449
sort of experiencing resurgence now and

15
00:00:52,880 --> 00:00:50,519
interest in the search for techno

16
00:00:54,559 --> 00:00:52,890
signatures which is this kind of new

17
00:00:56,959 --> 00:00:54,569
brand that talks about the same thing

18
00:00:59,630 --> 00:00:56,969
and so before I started I wanted to give

19
00:01:02,869 --> 00:00:59,640
a little bit of background on why I

20
00:01:05,870 --> 00:01:02,879
think study is a fruitful contribution

21
00:01:10,250 --> 00:01:05,880
to the field of astrobiology and why I

22
00:01:12,980 --> 00:01:10,260
personally have chosen to do it so for

23
00:01:15,170 --> 00:01:12,990
me there are two reasons that techno

24
00:01:17,720 --> 00:01:15,180
signatures tie very well into bio

25
00:01:19,640 --> 00:01:17,730
signatures one of these is that techno

26
00:01:22,250 --> 00:01:19,650
signatures could be more detectable than

27
00:01:25,700 --> 00:01:22,260
bio signatures if we're looking for life

28
00:01:27,290 --> 00:01:25,710
elsewhere in the universe it might be

29
00:01:29,180 --> 00:01:27,300
that we can find more detectable

30
00:01:30,770 --> 00:01:29,190
signatures by looking for something that

31
00:01:33,830 --> 00:01:30,780
intelligent or technological life is

32
00:01:36,830 --> 00:01:33,840
doing them by trying to maximize the

33
00:01:38,870 --> 00:01:36,840
signal-to-noise with instruments such as

34
00:01:41,300 --> 00:01:38,880
levar looking for say atmospheric bio

35
00:01:43,550 --> 00:01:41,310
signatures and another nice thing about

36
00:01:47,290 --> 00:01:43,560
techno signatures is in a lot of cases

37
00:01:49,070 --> 00:01:47,300
they have fewer natural confounders so

38
00:01:52,190 --> 00:01:49,080

specifically what I do is radio

39
00:01:54,020 --> 00:01:52,200
astronomy so if you see a very very

40
00:01:56,210 --> 00:01:54,030
narrow band radio signal coming from

41
00:01:58,520 --> 00:01:56,220
somewhere in the galaxy boom you've done

42
00:02:00,470 --> 00:01:58,530
it there's no natural Astrophysical

43
00:02:02,300 --> 00:02:00,480
phenomenon that we know of that could

44
00:02:03,820 --> 00:02:02,310
produce such a signal it has to be

45
00:02:08,109 --> 00:02:03,830
produced by some sort of synthetic

46
00:02:10,789 --> 00:02:08,119
synthesizer from a another intelligence

47
00:02:12,870 --> 00:02:10,799
whereas you have a lot of problems with

48
00:02:15,390 --> 00:02:12,880
a possible abiotic confounders

49
00:02:20,130 --> 00:02:15,400
or astrobiological systems atmospheres

50
00:02:23,430 --> 00:02:20,140
and that sort of thing so and I guess as

51
00:02:25,640 --> 00:02:23,440
a photo point i I see bio signatures and

52
00:02:27,870 --> 00:02:25,650
techno signatures is sort of a continuum

53
00:02:30,600 --> 00:02:27,880
we're talking a lot about say

54
00:02:32,970 --> 00:02:30,610
atmospheric bio signatures now if you

55
00:02:35,190 --> 00:02:32,980
don't see oxygen but you see a huge

56
00:02:37,080 --> 00:02:35,200
amount of chlorofluorocarbons or

57
00:02:38,340 --> 00:02:37,090
something like that suddenly your bio

58
00:02:40,170 --> 00:02:38,350
signature techno signature your line

59
00:02:41,730 --> 00:02:40,180
gets a little bit messy and so I think

60
00:02:44,000 --> 00:02:41,740
this is a really good time for the

61
00:02:45,660 --> 00:02:44,010
resurgence of this field and

62
00:02:47,640 --> 00:02:45,670
specifically what I'm going to be

63
00:02:49,650 --> 00:02:47,650

talking about is kind of the more

64
00:02:51,960 --> 00:02:49,660
traditional setting where we're looking

65
00:02:54,780 --> 00:02:51,970
for these radio signatures coming from

66
00:02:58,230 --> 00:02:54,790
somewhere else in the galaxy so with

67
00:02:59,970 --> 00:02:58,240
that background I'm going to start with

68
00:03:01,470 --> 00:02:59,980
my acknowledgments because science is a

69
00:03:04,020 --> 00:03:01,480
human endeavor and I could not have done

70
00:03:05,790 --> 00:03:04,030
this project without these humans Jason

71
00:03:08,400 --> 00:03:05,800
right my advisor at Penn State and

72
00:03:10,200 --> 00:03:08,410
Emilio Enriquez and Andrew Semien who

73
00:03:12,030 --> 00:03:10,210
are both part of the breakthrough listen

74
00:03:15,300 --> 00:03:12,040
initiative at the Berkeley City Research

75
00:03:18,270 --> 00:03:15,310
Center and this work that I'm presenting

76
00:03:21,140 --> 00:03:18,280
is currently in review and so hopefully

77
00:03:25,230 --> 00:03:21,150
will be published in say a month or so

78
00:03:28,200 --> 00:03:25,240
so I'm actually here going to show an

79
00:03:31,230 --> 00:03:28,210
edited version of a figure you saw a

80
00:03:33,030 --> 00:03:31,240
couple talks ago to point out but when

81
00:03:34,140 --> 00:03:33,040
we're looking for signals from radio

82
00:03:36,240 --> 00:03:34,150
transmitters somewhere else in the

83
00:03:39,600 --> 00:03:36,250
galaxy we have to think about how

84
00:03:41,580 --> 00:03:39,610
they're moving relative to us so because

85
00:03:43,470 --> 00:03:41,590
of the Doppler effect a transmitter

86
00:03:45,330 --> 00:03:43,480
that's moving towards us is going to

87
00:03:47,010 --> 00:03:45,340
appear at a higher frequency than it's

88
00:03:48,480 --> 00:03:47,020

actually transmitted I got and if it's

89
00:03:51,570 --> 00:03:48,490
moving away from us it's going to appear

90
00:03:53,580 --> 00:03:51,580
to lower frequency and this is important

91
00:03:55,170 --> 00:03:53,590
because when we think about where life

92
00:03:57,600 --> 00:03:55,180
is going to originate where intelligent

93
00:03:59,210 --> 00:03:57,610
life might be in the galaxy we usually

94
00:04:02,730 --> 00:03:59,220
think about planetary systems and

95
00:04:05,580 --> 00:04:02,740
planetary systems have orbits and they

96
00:04:07,199 --> 00:04:05,590
have bodies that are rotating and so

97
00:04:08,970 --> 00:04:07,209
these orbits and rotations are going to

98
00:04:12,330 --> 00:04:08,980
act movements toward and away from us

99
00:04:14,490 --> 00:04:12,340
and well the nice thing so we don't fit

100
00:04:16,500 --> 00:04:14,500
in SETI as we don't know what frequency

101
00:04:19,830 --> 00:04:16,510
this is going to be at inherently so

102
00:04:21,780 --> 00:04:19,840
whether it shows up at say 10 gigahertz

103
00:04:22,879 --> 00:04:21,790
or 4 gigahertz like we don't know what

104
00:04:25,070 --> 00:04:22,889
they're transmitting at

105
00:04:28,670 --> 00:04:25,080
so the actual Doppler shift doesn't

106
00:04:32,119 --> 00:04:28,680
matter too much but what does matter is

107
00:04:34,369 --> 00:04:32,129
if that velocity towards our way from us

108
00:04:37,010 --> 00:04:34,379
is changing over time then there's going

109
00:04:39,260 --> 00:04:37,020
to be some change in the frequency over

110
00:04:43,129 --> 00:04:39,270
time and that actually does matter

111
00:04:44,839 --> 00:04:43,139
ah so this here is an exoplanet radial

112
00:04:47,119 --> 00:04:44,849
velocity plot actually from one of the

113
00:04:49,670 --> 00:04:47,129

first exoplanets ever discovered and

114
00:04:51,529 --> 00:04:49,680
what you'll notice is think of this

115
00:04:53,570 --> 00:04:51,539
radial velocity as a frequency so this

116
00:04:55,580 --> 00:04:53,580
is your frequency axis it gets higher in

117
00:04:57,230 --> 00:04:55,590
frequency and then it gets lower in

118
00:05:00,350 --> 00:04:57,240
frequency over time and then it gets

119
00:05:01,610 --> 00:05:00,360
higher in frequency again and like I

120
00:05:03,890 --> 00:05:01,620
said in SETI we don't care what the

121
00:05:05,689 --> 00:05:03,900
actual frequency is but we do care about

122
00:05:08,570 --> 00:05:05,699
how quickly it's changing over time and

123
00:05:10,399 --> 00:05:08,580
that's called the drift rate so I've

124
00:05:12,769 --> 00:05:10,409
highlighted this region here in the

125
00:05:15,110 --> 00:05:12,779
yellow box this part of the radial

126
00:05:17,629 --> 00:05:15,120
velocity curve is where the frequency is

127
00:05:20,480 --> 00:05:17,639
changing the fastest over time so that's

128
00:05:21,800 --> 00:05:20,490
where the relative motion between us and

129
00:05:23,659 --> 00:05:21,810
the transmitter has the biggest effect

130
00:05:28,700 --> 00:05:23,669
on our signal and so that's what I want

131
00:05:31,689 --> 00:05:28,710
to think about so this plot is has a lot

132
00:05:34,459 --> 00:05:31,699
of stuff going on so I'll build it up so

133
00:05:37,159 --> 00:05:34,469
this is actually a plot of some data

134
00:05:39,969 --> 00:05:37,169
from a known extraterrestrial

135
00:05:41,809 --> 00:05:39,979
transmitter which is Voyager

136
00:05:45,499 --> 00:05:41,819
extraterrestrial in the literal sense of

137
00:05:47,689 --> 00:05:45,509
the word and what you're seeing here in

138
00:05:49,640 --> 00:05:47,699

these three panels are waterfall plots

139
00:05:51,279 --> 00:05:49,650
and we use these a lot in radio

140
00:05:55,339 --> 00:05:51,289
astronomy and what they show is

141
00:05:57,829 --> 00:05:55,349
frequency here on the x axis and time on

142
00:06:00,290 --> 00:05:57,839
the y axis and then the color shows you

143
00:06:02,360 --> 00:06:00,300
the intensity so this middle panel is

144
00:06:03,679 --> 00:06:02,370
the carrier wave of a Voyager and what I

145
00:06:05,899 --> 00:06:03,689
want you to get out of this is this is

146
00:06:09,110 --> 00:06:05,909
not a vertical one this line is sloped

147
00:06:10,999 --> 00:06:09,120
so this is the start of the observation

148
00:06:13,459 --> 00:06:11,009
and over time instead of going straight

149
00:06:16,040 --> 00:06:13,469
down staying at the same frequency you

150
00:06:18,140 --> 00:06:16,050
see it changing in frequency and this is

151
00:06:20,390 --> 00:06:18,150
important because luckily this

152
00:06:22,640 --> 00:06:20,400
particular slope is caused by the front

153
00:06:23,990 --> 00:06:22,650
rotation we know the Earth's rotation we

154
00:06:26,659 --> 00:06:24,000
can characterize that we can normalize

155
00:06:30,110 --> 00:06:26,669
it up and if we do that we get this nice

156
00:06:32,149 --> 00:06:30,120
sharp blue peak so yay we detected it at

157
00:06:35,300 --> 00:06:32,159
full signal-to-noise we know voyagers

158
00:06:35,800 --> 00:06:35,310
there that's great if you instead assume

159
00:06:36,730 --> 00:06:35,810
that

160
00:06:38,379 --> 00:06:36,740
it's gonna stay at the same frequency

161
00:06:40,330 --> 00:06:38,389
all the time and you don't account for

162
00:06:42,940 --> 00:06:40,340
the direct rate you get this red line

163
00:06:45,340 --> 00:06:42,950

and you notice suddenly you've lost a

164
00:06:46,629 --> 00:06:45,350
whole bunch of signal-to-noise it might

165
00:06:49,270 --> 00:06:46,639
be hard to tell that something's there

166
00:06:50,980 --> 00:06:49,280
you've lost the structure and so if

167
00:06:52,900 --> 00:06:50,990
you're not checking for all of these

168
00:06:56,440 --> 00:06:52,910
drift rates you might throw the baby out

169
00:06:59,080 --> 00:06:56,450
with the bathwater so how do we deal

170
00:07:00,490 --> 00:06:59,090
with that well like I said we don't know

171
00:07:02,650 --> 00:07:00,500
what frequency the signal is going to

172
00:07:05,230 --> 00:07:02,660
come at and we don't know what it's

173
00:07:06,520 --> 00:07:05,240
strict rates gonna be so the solution is

174
00:07:08,290 --> 00:07:06,530
we have to search all the frequencies

175
00:07:10,600 --> 00:07:08,300
and all the dearth traits in any data we

176
00:07:14,140 --> 00:07:10,610
get and if that sounds computationally

177
00:07:15,280 --> 00:07:14,150
expensive it is so unfortunately we

178
00:07:16,780 --> 00:07:15,290
can't go through all these waterfall

179
00:07:19,330 --> 00:07:16,790
plots by eye at this point we're just

180
00:07:21,520 --> 00:07:19,340
getting too many so we have to rely on

181
00:07:23,710 --> 00:07:21,530
algorithms and those algorithms have

182
00:07:27,909 --> 00:07:23,720
computation time and memory constraints

183
00:07:29,770 --> 00:07:27,919
so my first question when I ran into

184
00:07:31,210 --> 00:07:29,780
this problem was why don't you just

185
00:07:33,490 --> 00:07:31,220
search all the directories and the

186
00:07:34,810 --> 00:07:33,500
answer is it's just too expensive you

187
00:07:36,820 --> 00:07:34,820
don't want to waste time searching drift

188
00:07:38,140 --> 00:07:36,830

rates but aren't physical at all because

189
00:07:43,469 --> 00:07:38,150
they correspond to accelerations that

190
00:07:50,350 --> 00:07:47,200
basically the algorithms that we use to

191
00:07:52,450 --> 00:07:50,360
go through images and search for sloping

192
00:07:55,150 --> 00:07:52,460
lines searching for these drifting

193
00:07:56,740 --> 00:07:55,160
signals scale order n if you want to

194
00:08:00,130 --> 00:07:56,750
search twice as many drift rates it's

195
00:08:02,409 --> 00:08:00,140
gonna take you twice as long so how can

196
00:08:03,730 --> 00:08:02,419
we put reasonable bounds on the range of

197
00:08:06,520 --> 00:08:03,740
just rates who want our algorithms to

198
00:08:10,240 --> 00:08:06,530
search this question has been tackled

199
00:08:12,640 --> 00:08:10,250
before in 1971 and this was actually

200
00:08:14,620 --> 00:08:12,650
back when NASA was doing sunny so this

201
00:08:18,219 --> 00:08:14,630
was from the NASA project Cyclops report

202
00:08:20,980 --> 00:08:18,229
and there's this paragraph that I've

203
00:08:24,010 --> 00:08:20,990
highlighted some quotes out of that says

204
00:08:26,950 --> 00:08:24,020
okay well it's 1971 we don't know about

205
00:08:28,140 --> 00:08:26,960
any exoplanets so what do we know in our

206
00:08:31,450 --> 00:08:28,150
own solar system

207
00:08:34,329 --> 00:08:31,460
well Earth's rotation causes a dearth

208
00:08:36,579 --> 00:08:34,339
rate Jupiter has an eight-hour day which

209
00:08:39,339 --> 00:08:36,589
is the fastest rotation period in the

210
00:08:40,269 --> 00:08:39,349
solar system if an earth-like planet had

211
00:08:42,459 --> 00:08:40,279
an eight-hour day

212
00:08:45,010 --> 00:08:42,469
what drift rate would we get and so

213
00:08:47,130 --> 00:08:45,020

that's the math they did in 1971 and

214
00:08:50,850 --> 00:08:47,140
they said oh we get a drift rate

215
00:08:52,380 --> 00:08:50,860
10 to the negative 9 Nana hurts so it

216
00:08:54,900 --> 00:08:52,390
doesn't matter too much for this talk

217
00:08:57,090 --> 00:08:54,910
what those units are but it's drifting 1

218
00:08:59,400 --> 00:08:57,100
Hertz in frequency every second if

219
00:09:03,660 --> 00:08:59,410
you're observing it 1 gigahertz is what

220
00:09:05,280 --> 00:09:03,670
that means so they did that and then

221
00:09:07,290 --> 00:09:05,290
everybody in the community started using

222
00:09:09,000 --> 00:09:07,300
this as their standard they search for

223
00:09:14,040 --> 00:09:09,010
slopes up to 1 Nana Hertz and they're

224
00:09:15,750 --> 00:09:14,050
done cool now we know of exoplanets we

225
00:09:17,639 --> 00:09:15,760
know of a lot of we have a much larger

226
00:09:19,769 --> 00:09:17,649
sample size we know of a lot more that

227
00:09:22,230 --> 00:09:19,779
we could do to physically motivate that

228
00:09:24,300 --> 00:09:22,240
number but no one had done it so my

229
00:09:25,920 --> 00:09:24,310
question was could we take what we know

230
00:09:28,139 --> 00:09:25,930
about exoplanets I'm physically motivate

231
00:09:33,630 --> 00:09:28,149
that to see if we're choosing reasonable

232
00:09:35,400 --> 00:09:33,640
grades so you can break this problem

233
00:09:38,610 --> 00:09:35,410
down into pieces because they add

234
00:09:40,259 --> 00:09:38,620
linearly which is really nice so some of

235
00:09:41,639 --> 00:09:40,269
this we already know and this is the

236
00:09:44,009 --> 00:09:41,649
part that Oliver and Billingham kind of

237
00:09:45,750 --> 00:09:44,019
did where you say ok we know what the

238
00:09:47,579 --> 00:09:45,760

Earth's rotation is we can characterize

239
00:09:49,710 --> 00:09:47,589
that and we know what our orbit around

240
00:09:51,990 --> 00:09:49,720
the Sun is and so any relative motion

241
00:09:54,329 --> 00:09:52,000
from that we can correct out well we

242
00:09:56,220 --> 00:09:54,339
don't know is if we have a transmitter

243
00:09:58,740 --> 00:09:56,230
say sitting on a planet or in orbit

244
00:10:00,329 --> 00:09:58,750
around the star what's its rotation

245
00:10:02,519 --> 00:10:00,339
gonna be on that planet could even be on

246
00:10:04,410 --> 00:10:02,529
a moon with a rotation around a planet

247
00:10:06,030 --> 00:10:04,420
that's orbiting a star like you can make

248
00:10:10,290 --> 00:10:06,040
these systems arbitrarily complicated

249
00:10:12,269 --> 00:10:10,300
but there's some amount of terms there

250
00:10:14,460 --> 00:10:12,279
that you need to add into this side and

251
00:10:16,100 --> 00:10:14,470
that gives you your total relative

252
00:10:19,740 --> 00:10:16,110
acceleration so your total drift right

253
00:10:22,319 --> 00:10:19,750
so you can make this into an equation if

254
00:10:24,660 --> 00:10:22,329
you want and I've kind of color-coded

255
00:10:26,639 --> 00:10:24,670
the important terms here which is the

256
00:10:29,250 --> 00:10:26,649
yellow part is Earth's rotation and

257
00:10:31,319 --> 00:10:29,260
orbital motion cool we know that the

258
00:10:33,420 --> 00:10:31,329
pink part on the end here is all the

259
00:10:36,230 --> 00:10:33,430
radial accelerations which I included

260
00:10:38,280 --> 00:10:36,240
for completeness but that's say if

261
00:10:39,870 --> 00:10:38,290
someone out there made a even

262
00:10:41,340 --> 00:10:39,880
breakthrough starshot but the alien

263
00:10:43,710 --> 00:10:41,350

version have had something that was

264
00:10:45,900 --> 00:10:43,720
accelerating and transmitting it might

265
00:10:47,280 --> 00:10:45,910
have another term but we don't know

266
00:10:49,710 --> 00:10:47,290
anything about that so let's set that to

267
00:10:52,740 --> 00:10:49,720
zero so these are the two I focused on

268
00:10:54,780 --> 00:10:52,750
the rotation of whatever body is hosting

269
00:10:56,519 --> 00:10:54,790
the transmitter and then the orbital

270
00:10:56,910 --> 00:10:56,529
motion of whatever body so seeing the

271
00:11:01,049 --> 00:10:56,920
transfer

272
00:11:04,319 --> 00:11:01,059
and so what I did was I applied this to

273
00:11:06,419 --> 00:11:04,329
a bunch of different systems so I looked

274
00:11:07,619 --> 00:11:06,429
in the solar system basically doing what

275
00:11:09,929 --> 00:11:07,629
Oliver and Billingham did but with

276
00:11:12,689 --> 00:11:09,939
updated numbers solar system planets

277
00:11:14,069 --> 00:11:12,699
moons minor bodies so if there was a

278
00:11:14,519 --> 00:11:14,079
transmitter on a comment in our solar

279
00:11:16,139 --> 00:11:14,529
system

280
00:11:19,769 --> 00:11:16,149
what drift rate would that produce would

281
00:11:22,259 --> 00:11:19,779
we see that then I looked at rotation

282
00:11:24,059 --> 00:11:22,269
rates for exoplanets which unfortunately

283
00:11:27,329 --> 00:11:24,069
we don't have that much literature on

284
00:11:29,939 --> 00:11:27,339
right now but I did my best we looked at

285
00:11:32,400 --> 00:11:29,949
orbits from planets moons and exoplanets

286
00:11:34,079 --> 00:11:32,410
that are in very tight orbits around

287
00:11:36,119 --> 00:11:34,089
their host bodies which would maximize

288
00:11:38,909 --> 00:11:36,129

your acceleration and therefore maximize

289
00:11:41,009 --> 00:11:38,919
your drift rate we looked at orbits from

290
00:11:44,579 --> 00:11:41,019
minor bodies and exoplanets that are

291
00:11:47,129 --> 00:11:44,589
eccentric so when I say eccentric I mean

292
00:11:48,689 --> 00:11:47,139
really elliptical orbits and that the

293
00:11:49,829 --> 00:11:48,699
key with these is most of the time they

294
00:11:51,780 --> 00:11:49,839
won't give you very high dressed rates

295
00:11:53,699 --> 00:11:51,790
cuz they're going slow when they packed

296
00:11:56,340 --> 00:11:53,709
by the central body they're going really

297
00:11:58,889 --> 00:11:56,350
fast so I said what if you happen to

298
00:11:59,669 --> 00:11:58,899
catch it at this point from just the

299
00:12:02,720 --> 00:11:59,679
wrong angle

300
00:12:05,100 --> 00:12:02,730
what drift rate would you get and then

301
00:12:08,129 --> 00:12:05,110
so that included a little more because

302
00:12:10,470 --> 00:12:08,139
we wanted to do that for fun and finally

303
00:12:11,579 --> 00:12:10,480
we looked at orbits from okay what if

304
00:12:13,049 --> 00:12:11,589
the transmitter was around the black

305
00:12:14,609 --> 00:12:13,059
hole what if it was around a neutron

306
00:12:16,799 --> 00:12:14,619
star just trying to get kind of the most

307
00:12:19,650 --> 00:12:16,809
absurd scenarios to make sure all our

308
00:12:24,079 --> 00:12:19,660
bases were covered and at the same time

309
00:12:27,059 --> 00:12:24,089
we did some more theoretical work so

310
00:12:29,309 --> 00:12:27,069
what could our maximum upper limits be

311
00:12:30,479 --> 00:12:29,319
in different scenarios so one of them

312
00:12:33,090 --> 00:12:30,489
that we looked at was the break-up

313
00:12:34,859 --> 00:12:33,100

rotation rate for a spherical body so if

314
00:12:37,350 --> 00:12:34,869
you have a spherical body that's

315
00:12:39,960 --> 00:12:37,360
gravitationally bound and it's spinning

316
00:12:42,359 --> 00:12:39,970
really really fast eventually if you

317
00:12:44,429 --> 00:12:42,369
keep upping the velocity it'll throw

318
00:12:46,019 --> 00:12:44,439
itself apart where the centrifugal force

319
00:12:49,109 --> 00:12:46,029
on the equator is equal to the

320
00:12:50,609 --> 00:12:49,119
gravitational force so you can't have

321
00:12:52,409 --> 00:12:50,619
any rotation faster than that

322
00:12:54,650 --> 00:12:52,419
so we said that is our upper limit for

323
00:12:57,779 --> 00:12:54,660
rotation and tried some of those systems

324
00:13:01,199 --> 00:12:57,789
we tried theoretical systems that were

325
00:13:02,549 --> 00:13:01,209
doing surface grazing orbits so if your

326
00:13:04,349 --> 00:13:02,559
planet was literally touching the

327
00:13:07,300 --> 00:13:04,359
surface of the star you can't get much

328
00:13:10,480 --> 00:13:07,310
much faster than that

329
00:13:12,460 --> 00:13:10,490
and then we also looked at if you have

330
00:13:13,720 --> 00:13:12,470
one of those waterfall plots what's the

331
00:13:15,489 --> 00:13:13,730
maximum drift rate you could even

332
00:13:17,379 --> 00:13:15,499
observe so that would be the ultimate

333
00:13:20,800 --> 00:13:17,389
upper limit your instrumentation can't

334
00:13:22,749 --> 00:13:20,810
catch anything faster and we looked at

335
00:13:25,059 --> 00:13:22,759
people who have simulated planet

336
00:13:26,949 --> 00:13:25,069
formation and tracked rotation which is

337
00:13:29,920 --> 00:13:26,959
not very common but some people have

338
00:13:33,579 --> 00:13:29,930

done it and added those into our work as

339
00:13:36,670 --> 00:13:33,589
well so this is like the beautiful

340
00:13:39,999 --> 00:13:36,680
output of this project which is a table

341
00:13:41,439 --> 00:13:40,009
sorted by drift rate for all of these

342
00:13:43,900 --> 00:13:41,449
different systems so that I talked about

343
00:13:45,220 --> 00:13:43,910
in the past couple slides and there are

344
00:13:48,340 --> 00:13:45,230
a few things I want you to notice here

345
00:13:51,040 --> 00:13:48,350
the first one is this yellow bar at the

346
00:13:53,319 --> 00:13:51,050
top and that is the project cyclops

347
00:13:56,259 --> 00:13:53,329
recommendation that was the one Hertz

348
00:14:00,129 --> 00:13:56,269
per second at 1 gigahertz recommendation

349
00:14:01,480 --> 00:14:00,139
from NASA in 1971 and this table sorted

350
00:14:03,670 --> 00:14:01,490
by drift rate so you'll notice that

351
00:14:08,079 --> 00:14:03,680
anything above that line it would have

352
00:14:09,309 --> 00:14:08,089
caught if you used that cutoff and you

353
00:14:11,019 --> 00:14:09,319
took your data and ran it through one of

354
00:14:12,639 --> 00:14:11,029
those algorithms I mentioned you would

355
00:14:16,119 --> 00:14:12,649
get the signal at full signal-to-noise

356
00:14:18,400 --> 00:14:16,129
awesome anything below that line would

357
00:14:20,619 --> 00:14:18,410
not be caught including you'll notice a

358
00:14:25,689 --> 00:14:20,629
transmitter on i/o in our own solar

359
00:14:27,850 --> 00:14:25,699
system so that's no good and I wanted to

360
00:14:30,879 --> 00:14:27,860
show here breakthrough listen which is

361
00:14:33,340 --> 00:14:30,889
the biggest SETI search ever done is

362
00:14:35,650 --> 00:14:33,350
using something they were like a couple

363
00:14:38,699 --> 00:14:35,660

times the project Cyclops recommendation

364
00:14:41,590 --> 00:14:38,709
why not so they would catch everything

365
00:14:43,660 --> 00:14:41,600
here in the solar system but then they

366
00:14:45,100 --> 00:14:43,670
would miss some if there were

367
00:14:48,129 --> 00:14:45,110
transmitters on some of the exoplanets

368
00:14:52,179 --> 00:14:48,139
we knew ah they could be missed by

369
00:14:54,850 --> 00:14:52,189
breakthrough listens cutoff so with all

370
00:14:57,160 --> 00:14:54,860
that in mind we decided to recommend in

371
00:15:00,490 --> 00:14:57,170
this work the blue line here which is

372
00:15:03,910 --> 00:15:00,500
209 Hertz so 200 times what people were

373
00:15:06,790 --> 00:15:03,920
searching before to make sure that every

374
00:15:08,949 --> 00:15:06,800
observed system exoplanet system

375
00:15:11,679 --> 00:15:08,959
anything in the solar system would be

376
00:15:13,379 --> 00:15:11,689
caught by that recommendation and below

377
00:15:16,299 --> 00:15:13,389
that line I mean you can get up to

378
00:15:18,090 --> 00:15:16,309
ridiculous kind of arbitrarily high

379
00:15:20,340 --> 00:15:18,100
values here

380
00:15:21,689 --> 00:15:20,350
and basically what this tells you is if

381
00:15:23,400 --> 00:15:21,699
you want to look for transmitters around

382
00:15:25,079 --> 00:15:23,410
black holes you need a totally different

383
00:15:29,850 --> 00:15:25,089
survey design you can't keep using these

384
00:15:31,350 --> 00:15:29,860
same algorithms so I just kind of wanted

385
00:15:36,569 --> 00:15:31,360
to finish up with another view of that

386
00:15:37,860 --> 00:15:36,579
data so this is your frequency again so

387
00:15:39,900 --> 00:15:37,870
this is how much your frequency has

388
00:15:42,319 --> 00:15:39,910

changed over a 5-minute observation

389
00:15:46,079 --> 00:15:42,329
which is kind of standard for SETI and

390
00:15:49,019 --> 00:15:46,089
the pink line is project Cyclops so it

391
00:15:51,420 --> 00:15:49,029
catch anything kind of within this area

392
00:15:53,490 --> 00:15:51,430
but any higher slopes would be state

393
00:15:56,370 --> 00:15:53,500
so here's breakthrough listen with its

394
00:15:57,749 --> 00:15:56,380
grey line which does a lot better but

395
00:15:59,850 --> 00:15:57,759
would still miss if there was a

396
00:16:01,980 --> 00:15:59,860
transmitter on beta pick V which is a

397
00:16:03,920 --> 00:16:01,990
large gas giant exoplanet which is one

398
00:16:07,379 --> 00:16:03,930
of the few we have rotation rates for uh

399
00:16:08,850 --> 00:16:07,389
and I'm also showing this figure I'm

400
00:16:12,509 --> 00:16:08,860
sure you will notice this wonderful

401
00:16:14,160 --> 00:16:12,519
sinusoidal curve here and that's just a

402
00:16:16,710 --> 00:16:14,170
warning kind of warning to the audience

403
00:16:18,360 --> 00:16:16,720
that all of this only works if you can

404
00:16:20,819 --> 00:16:18,370
approximately direct rate is linear and

405
00:16:23,370 --> 00:16:20,829
if your observation time is really short

406
00:16:25,740 --> 00:16:23,380
compared to the orbital period or the

407
00:16:27,090 --> 00:16:25,750
rotational period you can do that but if

408
00:16:29,430 --> 00:16:27,100
you have something that's rotating

409
00:16:31,199 --> 00:16:29,440
really really fast for example like this

410
00:16:34,079 --> 00:16:31,209
particular asteroid in our solar system

411
00:16:35,970 --> 00:16:34,089
it had a transmitter on it your linear

412
00:16:38,009 --> 00:16:35,980
fits don't work anymore and so you have

413
00:16:39,480 --> 00:16:38,019

to keep that in mind that that's kind of

414
00:16:43,379 --> 00:16:39,490
a flaw in this method when you're using

415
00:16:45,900 --> 00:16:43,389
it so with that I just wanted to go

416
00:16:47,280 --> 00:16:45,910
through some takeaways the drift rates

417
00:16:49,290 --> 00:16:47,290
that could be produced by known

418
00:16:50,819 --> 00:16:49,300
Astrophysical systems greatly exceed the

419
00:16:52,439 --> 00:16:50,829
maximum drift rate that's been chosen by

420
00:16:55,590 --> 00:16:52,449
many SETI searches in the past which is

421
00:16:57,449 --> 00:16:55,600
not good we recommend using a maximum

422
00:16:59,009 --> 00:16:57,459
drift rate of 200 nano Hertz which is

423
00:17:00,689 --> 00:16:59,019
large enough to catch all of those known

424
00:17:04,169 --> 00:17:00,699
solar system objects and all known

425
00:17:06,299 --> 00:17:04,179
exoplanets and drift right scale

426
00:17:08,730 --> 00:17:06,309
linearly so using this more physically

427
00:17:10,860 --> 00:17:08,740
motivated maximum it's 200 times the

428
00:17:14,429 --> 00:17:10,870
computation time which is a lot but also

429
00:17:16,980 --> 00:17:14,439
it's easily parallelizable and so if you

430
00:17:19,530 --> 00:17:16,990
have the resources to go up to 200 it's

431
00:17:21,240 --> 00:17:19,540
a pretty reasonable proposition to it at

432
00:17:24,299 --> 00:17:21,250
least try going higher than this one

433
00:17:27,449 --> 00:17:24,309
Nana Hertz guideline that was proposed

434
00:17:29,260 --> 00:17:27,459
in the past so with that I will take any

435
00:17:36,970 --> 00:17:29,270
questions I'll leave these up and

436
00:17:46,060 --> 00:17:36,980
you for attention thank you very much

437
00:17:53,290 --> 00:17:51,460
hello little closer okay hi um so I have

438
00:17:55,060 --> 00:17:53,300

kind of a philosophical question for you

439
00:18:01,480 --> 00:17:55,070
I'm interested to hear your thoughts on

440
00:18:04,630 --> 00:18:01,490
like Dyson spheres and transitioning

441
00:18:06,040 --> 00:18:04,640
study into photometry and do you think

442
00:18:10,690 --> 00:18:06,050
that's a good idea

443
00:18:12,900 --> 00:18:10,700
or yeah just one any thoughts my thought

444
00:18:15,250 --> 00:18:12,910
is that it's an excellent idea and that

445
00:18:17,050 --> 00:18:15,260
broadening what techno signature means

446
00:18:20,620 --> 00:18:17,060
and I'm having that new label helps a

447
00:18:21,520 --> 00:18:20,630
lot to is very important and thinking

448
00:18:23,380 --> 00:18:21,530
about all of the different ways that

449
00:18:25,390 --> 00:18:23,390
technology impacts its environment so

450
00:18:27,100 --> 00:18:25,400
kind of like I was saying thinking about

451
00:18:28,840 --> 00:18:27,110
it in a spectral way when you're looking

452
00:18:30,040 --> 00:18:28,850
at exoplanet atmospheres what signatures

453
00:18:34,780 --> 00:18:30,050
could technology leave

454
00:18:36,250 --> 00:18:34,790
their ideas like looking for belts of

455
00:18:38,410 --> 00:18:36,260
satellites around planets the way we

456
00:18:40,890 --> 00:18:38,420
look for two moons automatically or

457
00:18:44,230 --> 00:18:40,900
Dyson spheres and I think they're all

458
00:18:45,580 --> 00:18:44,240
pieces in this larger puzzle and none of

459
00:18:47,350 --> 00:18:45,590
them have been explored very well in the

460
00:18:49,750 --> 00:18:47,360
past so there's a lot of work yet to do

461
00:18:52,660 --> 00:18:49,760
and we should be using all of the tools

462
00:18:54,550 --> 00:18:52,670
that we have so I do radio SETI because

463
00:18:56,080 --> 00:18:54,560

that's where I started I'm a radio

464
00:18:58,840 --> 00:18:56,090
astronomer but I do want to branch out

465
00:18:59,830 --> 00:18:58,850
into more types of techno signatures

466
00:19:05,610 --> 00:18:59,840
because I think they're all very