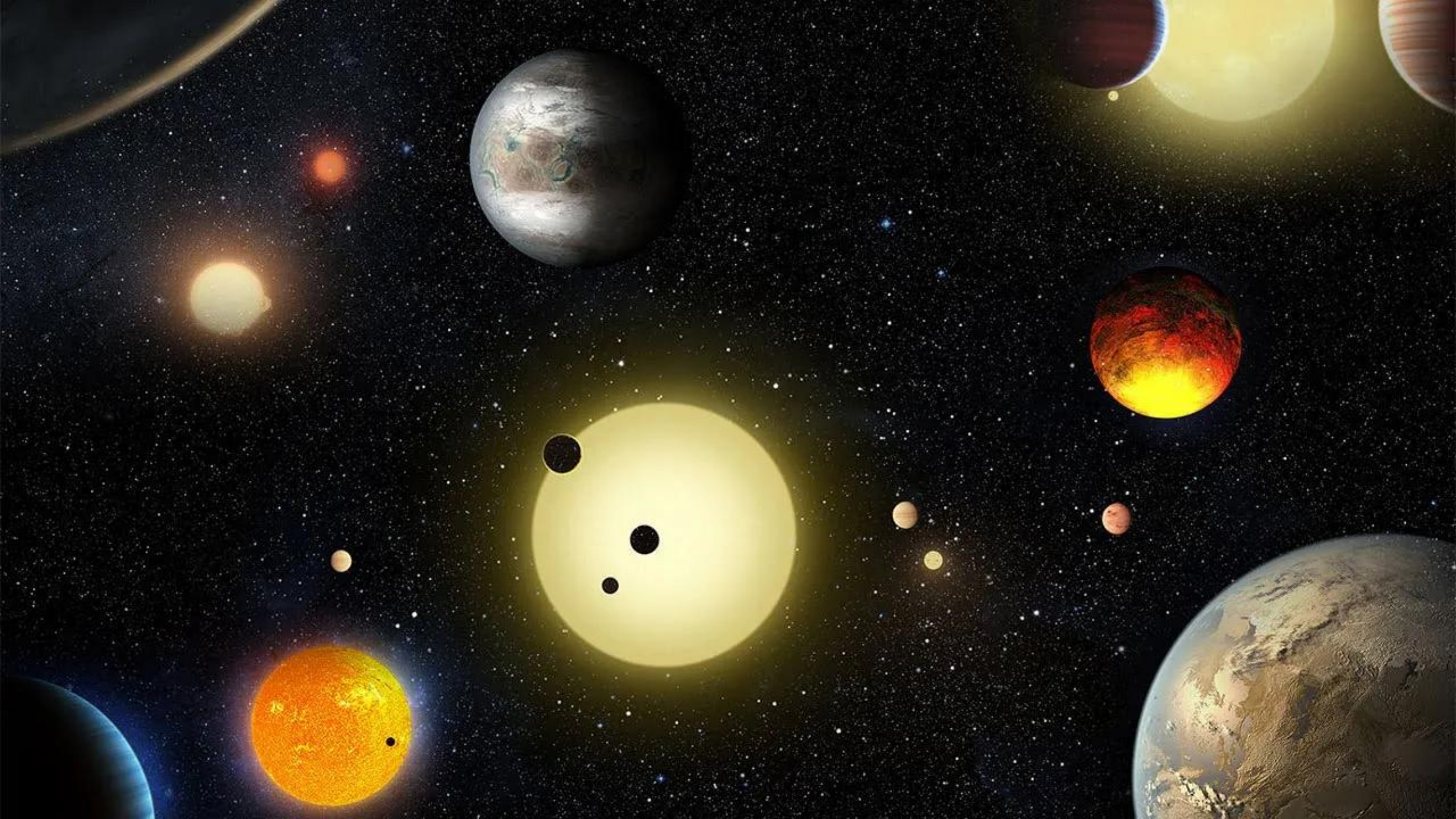

1
00:00:03,350 --> 00:00:02,030
NASA's jet propulsion laboratory

2
00:00:06,410 --> 00:00:03,360
presents

3
00:00:08,450 --> 00:00:06,420
the Von Carmen lecture a series of Talks

4
00:00:11,209 --> 00:00:08,460
by scientists and Engineers who are

5
00:00:13,210 --> 00:00:11,219
exploring our planet our solar system

6
00:00:19,310 --> 00:00:13,220
and all that lies Beyond

7
00:00:21,529 --> 00:00:19,320
[Music]

8
00:00:23,689 --> 00:00:21,539
hello and a very pleasant good evening

9
00:00:25,310 --> 00:00:23,699
to you wherever you may be I am Brian

10
00:00:27,890 --> 00:00:25,320
White from jpl's Office of

11
00:00:31,790 --> 00:00:27,900
communications and education and welcome

12
00:00:34,010 --> 00:00:31,800
to the final Von Carmen talk of 2022.

13
00:00:35,389 --> 00:00:34,020

from Star Trek to Kurt Vonnegut and all

14
00:00:37,069 --> 00:00:35,399
the Sci-Fi in between people have

15
00:00:39,590 --> 00:00:37,079
dreamed of planets beyond our home

16
00:00:41,389 --> 00:00:39,600
beyond our system in the past 30 some

17
00:00:43,310 --> 00:00:41,399
odd years these dreams have become more

18
00:00:44,990 --> 00:00:43,320
of a reality with the field of exoplanet

19
00:00:47,569 --> 00:00:45,000
discovery

20
00:00:50,389 --> 00:00:47,579
in this scheme the nearest known

21
00:00:52,250 --> 00:00:50,399
exoplanet orbits Proxima Centauri the

22
00:00:53,690 --> 00:00:52,260
next star over from Earth and it's a

23
00:00:58,069 --> 00:00:53,700
little more than four light years away

24
00:01:00,049 --> 00:00:58,079
or 24 trillion miles if an airline

25
00:01:03,049 --> 00:01:00,059
offered a flight there by jet it would

26
00:01:05,990 --> 00:01:03,059
take you 5 million years to get there

27
00:01:07,969 --> 00:01:06,000
however exoplanets offer a unique view

28
00:01:08,810 --> 00:01:07,979
of our solar system and of our home

29
00:01:10,550 --> 00:01:08,820
planet

30
00:01:12,289 --> 00:01:10,560
now I'd like to introduce our questions

31
00:01:15,890 --> 00:01:12,299
co-host for tonight a public Outreach

32
00:01:18,230 --> 00:01:15,900
specialist here at JPL Dr Nora Bailey

33
00:01:20,270 --> 00:01:18,240
thanks Brian and hello everyone remember

34
00:01:21,649 --> 00:01:20,280
this is your space program and we really

35
00:01:23,690 --> 00:01:21,659
want you to be involved with this

36
00:01:26,149 --> 00:01:23,700
conversation so if you're watching on

37
00:01:27,410 --> 00:01:26,159
YouTube or Facebook live or LinkedIn you

38
00:01:29,870 --> 00:01:27,420

can go ahead and submit any questions

39
00:01:31,429 --> 00:01:29,880
into the chat box right there and our

40
00:01:33,109 --> 00:01:31,439
social media team will bring in as many

41
00:01:35,030 --> 00:01:33,119
as possible as we can into our talk

42
00:01:36,410 --> 00:01:35,040
tonight if you don't see the chat box go

43
00:01:38,270 --> 00:01:36,420
ahead and reload the page and it should

44
00:01:40,969 --> 00:01:38,280
be right there

45
00:01:43,010 --> 00:01:40,979
thank you Nora now our speaker tonight

46
00:01:45,770 --> 00:01:43,020
is a technologist for the Nancy Grace

47
00:01:47,390 --> 00:01:45,780
Roman Space Telescope CGI she received

48
00:01:49,850 --> 00:01:47,400
her PhD in astrophysics from the

49
00:01:52,249 --> 00:01:49,860
University Joseph Fourier in France was

50
00:01:54,770 --> 00:01:52,259
awarded jwst time through several go

51
00:01:56,149 --> 00:01:54,780
programs including one as a pi and when

52
00:01:57,410 --> 00:01:56,159
she's not working you can find her

53
00:02:00,170 --> 00:01:57,420
exploring National Parks from

54
00:02:03,710 --> 00:02:00,180
Yellowstone to moanaloa or to the

55
00:02:05,389 --> 00:02:03,720
Everglades please welcome Dr Marie igoof

56
00:02:09,290 --> 00:02:05,399
hello

57
00:02:12,290 --> 00:02:09,300
how are you today

58
00:02:13,670 --> 00:02:12,300
very good very pleased to be here well

59
00:02:15,710 --> 00:02:13,680
it's wonderful to have you here let's

60
00:02:17,270 --> 00:02:15,720
just dive in let's start with um let's

61
00:02:18,530 --> 00:02:17,280
just start with the main topic what are

62
00:02:19,670 --> 00:02:18,540
exoplins what are we talking about

63
00:02:20,930 --> 00:02:19,680

tonight

64
00:02:24,530 --> 00:02:20,940
yeah

65
00:02:27,710 --> 00:02:24,540
so exoplanets are planets that are

66
00:02:30,110 --> 00:02:27,720
located outside of our solar system

67
00:02:33,949 --> 00:02:30,120
Those Distant words are extremely

68
00:02:35,750 --> 00:02:33,959
diverse and although some may look very

69
00:02:38,210 --> 00:02:35,760
similar to the planets of our solar

70
00:02:40,790 --> 00:02:38,220
system we know for sure that some some

71
00:02:42,949 --> 00:02:40,800
of them are actually pretty different so

72
00:02:45,170 --> 00:02:42,959
let's have a look at the first slide

73
00:02:48,410 --> 00:02:45,180
please

74
00:02:50,990 --> 00:02:48,420
yeah so as a reminder we have two types

75
00:02:53,930 --> 00:02:51,000
of planets in our solar system on one

76
00:02:56,390 --> 00:02:53,940
side we have the small rocky planet that

77
00:02:57,530 --> 00:02:56,400
are also the closest to the Sun they are

78
00:03:00,830 --> 00:02:57,540
called Mercury

79
00:03:03,350 --> 00:03:00,840
Venus the Earth and Mars and on the

80
00:03:06,530 --> 00:03:03,360
other side we have the gazi giant

81
00:03:09,050 --> 00:03:06,540
planets that are also the furthest from

82
00:03:12,470 --> 00:03:09,060
the Sun they are called Jupiter Saturn

83
00:03:15,470 --> 00:03:12,480
Neptune and Uranus and before

84
00:03:18,050 --> 00:03:15,480
discovering the presence of exoplanets

85
00:03:20,690 --> 00:03:18,060
the solar system was the only model of

86
00:03:22,610 --> 00:03:20,700
planetary system we could think of and

87
00:03:25,670 --> 00:03:22,620
it was very hard to think about other

88
00:03:27,890 --> 00:03:25,680

models of exoplanetary systems

89
00:03:29,270 --> 00:03:27,900
so with that of thinking of ideas of

90
00:03:31,250 --> 00:03:29,280
different models and different systems

91
00:03:34,550 --> 00:03:31,260
how are these exoplanets teaching us

92
00:03:38,350 --> 00:03:34,560
about our solar system

93
00:03:41,270 --> 00:03:38,360
yeah so one thing we learned by studying

94
00:03:43,130 --> 00:03:41,280
exoplanets is the existence of planets

95
00:03:47,570 --> 00:03:43,140
that are dramatically different from the

96
00:03:49,630 --> 00:03:47,580
planet of a solar system so on slide two

97
00:03:52,910 --> 00:03:49,640
um we can see it so the the first planet

98
00:03:57,350 --> 00:03:52,920
uh discovered around a solar type star

99
00:03:59,990 --> 00:03:57,360
in 1995 by Nobel prizes Michael Meyer

100
00:04:02,869 --> 00:04:00,000
and DJ kelos was pretty a pretty

101
00:04:05,869 --> 00:04:02,879
different kind of object it's it's a

102
00:04:08,509 --> 00:04:05,879
gaseous Planet much larger than the

103
00:04:09,170 --> 00:04:08,519
earth and situated much closer to its

104
00:04:12,530 --> 00:04:09,180
star

105
00:04:15,589 --> 00:04:12,540
and it only takes four days to complete

106
00:04:17,750 --> 00:04:15,599
its orbits around its star and as a

107
00:04:19,849 --> 00:04:17,760
comparison Mercury which is the closest

108
00:04:23,390 --> 00:04:19,859
planet in our solar system orbits the

109
00:04:26,030 --> 00:04:23,400
Sun in 88 days so this type of Planet

110
00:04:28,969 --> 00:04:26,040
it's is definitely not something we can

111
00:04:31,850 --> 00:04:28,979
see in our solar system

112
00:04:34,670 --> 00:04:31,860
could you bring also a slight free

113
00:04:41,030 --> 00:04:37,550

and so since since that Discovery we

114
00:04:42,710 --> 00:04:41,040
found many other exotic planets that

115
00:04:45,170 --> 00:04:42,720
don't have equivalent in our solar

116
00:04:48,409 --> 00:04:45,180
system such as an entire new category of

117
00:04:51,170 --> 00:04:48,419
planets of size between the size of the

118
00:04:55,010 --> 00:04:51,180
Earth and the size of Neptune that we

119
00:04:58,969 --> 00:04:55,020
call either super Earth or mini Neptunes

120
00:05:02,270 --> 00:04:58,979
we also have lava words perfy planets

121
00:05:05,030 --> 00:05:02,280
that have the density of Styrofoam and

122
00:05:07,490 --> 00:05:05,040
also dense core of planets that are

123
00:05:08,749 --> 00:05:07,500
still orbiting their stars but without

124
00:05:11,030 --> 00:05:08,759
any

125
00:05:13,550 --> 00:05:11,040
atmosphere

126
00:05:17,570 --> 00:05:13,560
um we also have planets orbiting groups

127
00:05:19,610 --> 00:05:17,580
of stars uh also beating dead stars and

128
00:05:21,590 --> 00:05:19,620
even World planet that doesn't even

129
00:05:23,870 --> 00:05:21,600
orbit around the star

130
00:05:26,810 --> 00:05:23,880
um we have exempt highly eccentric

131
00:05:29,150 --> 00:05:26,820
eccentric planets and in fact many of

132
00:05:31,370 --> 00:05:29,160
the exoplanet discovered so far have a

133
00:05:32,870 --> 00:05:31,380
higher orbital eccentricity than the

134
00:05:37,010 --> 00:05:32,880
planet in our solar system

135
00:05:40,490 --> 00:05:37,020
so studying those exoplanets teaches us

136
00:05:43,189 --> 00:05:40,500
a lot about our own solar system for

137
00:05:44,990 --> 00:05:43,199
example it is very possible that we had

138
00:05:47,270 --> 00:05:45,000

a super Earth in the past that we have

139
00:05:50,150 --> 00:05:47,280
been expected from ocelots from the

140
00:05:52,670 --> 00:05:50,160
solar system also collided with against

141
00:05:54,710 --> 00:05:52,680
giant it's even possible that it's still

142
00:05:56,210 --> 00:05:54,720
here somewhere and we haven't find it

143
00:05:57,890 --> 00:05:56,220
yet

144
00:05:59,570 --> 00:05:57,900
well you talk about all these different

145
00:06:01,390 --> 00:05:59,580
types of planets planets that we kind of

146
00:06:05,390 --> 00:06:01,400
don't even think of in our solar system

147
00:06:08,629 --> 00:06:05,400
how many planets have we discovered

148
00:06:10,969 --> 00:06:08,639
yeah so can you bring in the slateful

149
00:06:15,170 --> 00:06:10,979
please

150
00:06:17,689 --> 00:06:15,180
so as the first uh of November

151
00:06:20,390 --> 00:06:17,699
um there were more than five uh thousand

152
00:06:24,110 --> 00:06:20,400
confirmed exoplanets and more than five

153
00:06:25,670 --> 00:06:24,120
nine thousand candidates uh needed to be

154
00:06:27,650 --> 00:06:25,680
confirmed

155
00:06:29,570 --> 00:06:27,660
um and uh one telescope that that

156
00:06:32,870 --> 00:06:29,580
revolutionized exoplanet Direction

157
00:06:36,830 --> 00:06:32,880
detections was Kepler the kepler-based

158
00:06:39,590 --> 00:06:36,840
telescope that was launched in 2009 and

159
00:06:42,650 --> 00:06:39,600
one of Kepler's findings is that there

160
00:06:46,670 --> 00:06:42,660
is at least one planet on average per

161
00:06:49,249 --> 00:06:46,680
star and as a matter of perspective our

162
00:06:52,430 --> 00:06:49,259
galaxy The Milky Way that you can see on

163
00:06:54,409 --> 00:06:52,440

this picture has a couple of hundreds of

164
00:06:57,050 --> 00:06:54,419
billions of stars

165
00:07:00,590 --> 00:06:57,060
so that means that we discovered only a

166
00:07:03,290 --> 00:07:00,600
tiny tiny fraction of exoplanets in our

167
00:07:05,870 --> 00:07:03,300
galaxy so there is there is quite a lot

168
00:07:08,270 --> 00:07:05,880
of room for incredible discoveries out

169
00:07:11,749 --> 00:07:08,280
there in the field of exoplanets

170
00:07:14,870 --> 00:07:11,759
so to diving a little bit more let's

171
00:07:16,909 --> 00:07:14,880
have a look at the slide uh five the

172
00:07:20,089 --> 00:07:16,919
discovery timeline of those exoplanets

173
00:07:23,809 --> 00:07:20,099
so this figure shows the number of

174
00:07:26,150 --> 00:07:23,819
detected planets as a function of time

175
00:07:30,290 --> 00:07:26,160
and we can see that this number is

176
00:07:33,290 --> 00:07:30,300
increasing as an exponential speed

177
00:07:35,710 --> 00:07:33,300
um the first discover planet was in the

178
00:07:40,309 --> 00:07:35,720
19th uh

179
00:07:41,809 --> 00:07:40,319
1990s and as you can see this is a

180
00:07:43,909 --> 00:07:41,819
pretty young film I mean it's less than

181
00:07:47,029 --> 00:07:43,919
30 years

182
00:07:50,210 --> 00:07:47,039
um and exoplanet Discovery is almost 14

183
00:07:53,930 --> 00:07:50,220
now we can say that and because other

184
00:07:57,350 --> 00:07:53,940
those those years we discovered One

185
00:07:58,689 --> 00:07:57,360
Planet every two days in average

186
00:08:02,390 --> 00:07:58,699
so

187
00:08:04,249 --> 00:08:02,400
of course this was not linear uh because

188
00:08:06,890 --> 00:08:04,259

we started with a pretty small Discovery

189
00:08:09,529 --> 00:08:06,900
rate and then we the dedicating missions

190
00:08:12,230 --> 00:08:09,539
uh were built to to detect those those

191
00:08:15,230 --> 00:08:12,240
planets and with every new Mission the

192
00:08:16,969 --> 00:08:15,240
the yelt of planets grew larger and

193
00:08:24,170 --> 00:08:16,979
larger

194
00:08:26,570 --> 00:08:24,180
um how how do you find them how do we

195
00:08:28,790 --> 00:08:26,580
discover these planets out there

196
00:08:30,409 --> 00:08:28,800
yeah so

197
00:08:31,610 --> 00:08:30,419
um another thing that we can see on that

198
00:08:34,070 --> 00:08:31,620
figure

199
00:08:36,469 --> 00:08:34,080
um is that the majority of detected

200
00:08:38,930 --> 00:08:36,479
planets have been discovered using two

201
00:08:40,909 --> 00:08:38,940
main techniques the radial velocity

202
00:08:41,990 --> 00:08:40,919
technique and the transit technique so

203
00:08:44,329 --> 00:08:42,000
we'll see

204
00:08:47,509 --> 00:08:44,339
um what are those techniques uh so the

205
00:08:50,930 --> 00:08:47,519
first illustration uh six expression six

206
00:08:53,509 --> 00:08:50,940
uh will show a little movie of the

207
00:08:56,509 --> 00:08:53,519
radial velocity technique so with that

208
00:08:59,750 --> 00:08:56,519
Technique we detect the tiny movements

209
00:09:00,590 --> 00:08:59,760
perturbation and exoplanet has on its

210
00:09:03,350 --> 00:09:00,600
star

211
00:09:05,449 --> 00:09:03,360
uh that slight movement affect the Stars

212
00:09:08,150 --> 00:09:05,459
normal light spectrum or colored

213
00:09:10,790 --> 00:09:08,160

signature and the spectrum of the star

214
00:09:13,790 --> 00:09:10,800
that is moving toward us toward us

215
00:09:15,710 --> 00:09:13,800
appears slightly shifted toward Bluer

216
00:09:18,350 --> 00:09:15,720
and shorter wavelength while when the

217
00:09:20,630 --> 00:09:18,360
star is moving away its spectrum is

218
00:09:22,430 --> 00:09:20,640
shift shifted toward redder and longer

219
00:09:25,430 --> 00:09:22,440
wavelengths

220
00:09:28,070 --> 00:09:25,440
so that's for the registry method and in

221
00:09:31,250 --> 00:09:28,080
the next movie we'll see the transit

222
00:09:37,850 --> 00:09:33,949
uh and so with that Technique we measure

223
00:09:39,350 --> 00:09:37,860
how the Luminosity of a star evolves

224
00:09:41,329 --> 00:09:39,360
over time

225
00:09:44,750 --> 00:09:41,339
so most of the time

226
00:09:45,670 --> 00:09:44,760
that Luminosity is constant and quite

227
00:09:49,370 --> 00:09:45,680
boring

228
00:09:52,370 --> 00:09:49,380
but some variable star

229
00:09:55,370 --> 00:09:52,380
um we we will see in those viable stars

230
00:09:57,470 --> 00:09:55,380
that this limited numinosity can vary in

231
00:09:59,150 --> 00:09:57,480
a random fashion because of the activity

232
00:10:02,389 --> 00:09:59,160
of the star itself

233
00:10:05,210 --> 00:10:02,399
but in some very rare occasion we can

234
00:10:08,449 --> 00:10:05,220
see periodic decreases of the Luminosity

235
00:10:10,310 --> 00:10:08,459
of that star which indicates that one or

236
00:10:12,410 --> 00:10:10,320
several planets are passing in front of

237
00:10:15,470 --> 00:10:12,420
the star

238
00:10:18,050 --> 00:10:15,480

so those those techniques um are what we

239
00:10:20,930 --> 00:10:18,060
call in direct technique because

240
00:10:24,110 --> 00:10:20,940
exoplanets are detected through the

241
00:10:26,570 --> 00:10:24,120
indirect effect they have on their ostar

242
00:10:28,550 --> 00:10:26,580
but we don't actually see the planet

243
00:10:30,170 --> 00:10:28,560
themselves

244
00:10:32,870 --> 00:10:30,180
well if you're calling these indirect

245
00:10:34,430 --> 00:10:32,880
techniques if we flip the coin do we

246
00:10:36,650 --> 00:10:34,440
have direct techniques are there more

247
00:10:39,050 --> 00:10:36,660
direct ways to find these planets

248
00:10:40,670 --> 00:10:39,060
yeah I'll show you what you're gonna ask

249
00:10:43,490 --> 00:10:40,680
that so yeah

250
00:10:45,290 --> 00:10:43,500
um also this this is pretty challenging

251
00:10:47,810 --> 00:10:45,300
as you can imagine that we'll see that

252
00:10:50,870 --> 00:10:47,820
there's another technique some

253
00:10:52,490 --> 00:10:50,880
astronomers and myself in particular

254
00:10:55,310 --> 00:10:52,500
um interested in

255
00:10:57,170 --> 00:10:55,320
uh this uh technique is called direct

256
00:10:59,150 --> 00:10:57,180
Imaging or so-called high contrast

257
00:11:02,389 --> 00:10:59,160
Imaging

258
00:11:04,730 --> 00:11:02,399
um and so what what is interesting with

259
00:11:07,370 --> 00:11:04,740
this technique is that we can actually

260
00:11:09,710 --> 00:11:07,380
get picture of those words

261
00:11:11,269 --> 00:11:09,720
and this is a game changing technique

262
00:11:13,069 --> 00:11:11,279
because first of all the type of

263
00:11:15,410 --> 00:11:13,079

exoplanet that we can detect with this

264
00:11:17,569 --> 00:11:15,420
technique is very different from the

265
00:11:19,910 --> 00:11:17,579
example that we can detect with other in

266
00:11:22,370 --> 00:11:19,920
an indirect techniques

267
00:11:24,710 --> 00:11:22,380
um the second thing is that we can know

268
00:11:27,769 --> 00:11:24,720
exactly where the planet is and learn

269
00:11:28,790 --> 00:11:27,779
about the the orbits of the of those

270
00:11:32,329 --> 00:11:28,800
planets

271
00:11:35,509 --> 00:11:32,339
and finally we can directly probe the

272
00:11:38,690 --> 00:11:35,519
chemical component of that atmosphere at

273
00:11:39,850 --> 00:11:38,700
different wavelength and learn crucial

274
00:11:43,370 --> 00:11:39,860
information

275
00:11:44,930 --> 00:11:43,380
on those planets such as their mass and

276
00:11:47,329 --> 00:11:44,940
their gravity and whether certain

277
00:11:49,009 --> 00:11:47,339
chemical components are present in their

278
00:11:53,690 --> 00:11:49,019
atmosphere

279
00:12:00,050 --> 00:11:56,389
um now we have

280
00:12:02,870 --> 00:12:00,060
only a few pictures of those exoplanets

281
00:12:04,250 --> 00:12:02,880
so far and the reason is that it is

282
00:12:07,730 --> 00:12:04,260
pretty challenging

283
00:12:10,009 --> 00:12:07,740
see because the star is so bright that

284
00:12:12,050 --> 00:12:10,019
we first need to block its light to be

285
00:12:13,370 --> 00:12:12,060
able to see the light of the faint

286
00:12:15,530 --> 00:12:13,380
planets

287
00:12:18,949 --> 00:12:15,540
and we are doing that by using a very

288
00:12:22,490 --> 00:12:18,959

small Optical component that is called a

289
00:12:26,269 --> 00:12:22,500
chronograph that acts similarly to what

290
00:12:27,230 --> 00:12:26,279
the moon does to the Sun during a solar

291
00:12:30,670 --> 00:12:27,240
eclipse

292
00:12:34,430 --> 00:12:30,680
so we can see an illustration nine

293
00:12:38,030 --> 00:12:34,440
uh the picture of

294
00:12:40,610 --> 00:12:38,040
such as a lot of cliffs and if you are

295
00:12:42,889 --> 00:12:40,620
lucky enough to have experienced a solar

296
00:12:45,650 --> 00:12:42,899
eclipse I really recommend that see if

297
00:12:49,129 --> 00:12:45,660
you have The Chins only you may have

298
00:12:50,509 --> 00:12:49,139
noticed that we can see stars in the

299
00:12:52,310 --> 00:12:50,519
middle of the day

300
00:12:54,889 --> 00:12:52,320
and with a choreograph we can do the

301
00:12:56,509 --> 00:12:54,899
same with any Star and hunt for planet

302
00:13:01,509 --> 00:12:56,519
that orbit around them

303
00:13:04,069 --> 00:13:01,519
but the extreme contrast of flux between

304
00:13:05,569 --> 00:13:04,079
the planet and its star

305
00:13:07,370 --> 00:13:05,579
is

306
00:13:11,389 --> 00:13:07,380
um not the only challenge we're facing

307
00:13:14,350 --> 00:13:11,399
we also need enough resolving power to

308
00:13:17,210 --> 00:13:14,360
be able to separate angularly the planet

309
00:13:19,430 --> 00:13:17,220
from the star in the image formed by the

310
00:13:22,730 --> 00:13:19,440
telescope and

311
00:13:26,750 --> 00:13:22,740
so that it really helps to have a big

312
00:13:29,269 --> 00:13:26,760
size telescope and it also helps to

313
00:13:31,129 --> 00:13:29,279

observe star that not too far from us

314
00:13:32,930 --> 00:13:31,139
which limit a little bit the number of

315
00:13:35,329 --> 00:13:32,940
Target that we can

316
00:13:38,090 --> 00:13:35,339
um observe with that technique

317
00:13:41,269 --> 00:13:38,100
and one of the other challenge of direct

318
00:13:43,250 --> 00:13:41,279
Imaging is that we need telescopes that

319
00:13:45,889 --> 00:13:43,260
are sensitive enough to detect the

320
00:13:48,590 --> 00:13:45,899
various faint signal from the planet and

321
00:13:50,569 --> 00:13:48,600
here again telescope with big mirrors

322
00:13:52,670 --> 00:13:50,579
help for that

323
00:13:54,829 --> 00:13:52,680
and also telescopes that are in space

324
00:13:56,269 --> 00:13:54,839
are sometimes more sensitive than

325
00:13:57,949 --> 00:13:56,279
telescope on the ground depending on

326
00:14:00,829 --> 00:13:57,959
whether we are observing in the infrared

327
00:14:01,850 --> 00:14:00,839
the visible or over wavelengths

328
00:14:03,769 --> 00:14:01,860
so you talk about these different

329
00:14:05,030 --> 00:14:03,779
wavelengths you're talking about these I

330
00:14:06,910 --> 00:14:05,040
mean it sounds like there are a lot of

331
00:14:10,430 --> 00:14:06,920
challenges in order to try to discover

332
00:14:13,009 --> 00:14:10,440
anything out there

333
00:14:14,990 --> 00:14:13,019
yeah yeah there are definitely a lot of

334
00:14:18,769 --> 00:14:15,000
Engineers so

335
00:14:20,750 --> 00:14:18,779
look at the illustration 10 uh I'd like

336
00:14:23,509 --> 00:14:20,760
to to show you a video that illustrates

337
00:14:26,329 --> 00:14:23,519
how we solve the contrast issue with

338
00:14:29,210 --> 00:14:26,339

with a chronograph I think it's a very

339
00:14:30,350 --> 00:14:29,220
very nice video uh so you you'll see

340
00:14:33,230 --> 00:14:30,360
here

341
00:14:35,449 --> 00:14:33,240
um an exoplanetary system orbiting your

342
00:14:37,850 --> 00:14:35,459
star and you want to observe that system

343
00:14:41,509 --> 00:14:37,860
with a telescope

344
00:14:42,530 --> 00:14:41,519
so the light is going to go through the

345
00:14:44,329 --> 00:14:42,540
telescope

346
00:14:46,870 --> 00:14:44,339
and we're gonna see what's happening

347
00:14:49,670 --> 00:14:46,880
inside the telescope

348
00:14:51,290 --> 00:14:49,680
uh so here the light is gonna first

349
00:14:55,250 --> 00:14:51,300
reach a mirror and then a couple of

350
00:14:59,150 --> 00:14:55,260
Optics and create the image of the star

351
00:15:01,910 --> 00:14:59,160
uh on the on the dictator and then you

352
00:15:04,370 --> 00:15:01,920
have a chronograph that you put in there

353
00:15:06,290 --> 00:15:04,380
uh to remove most of the Starlight so

354
00:15:07,910 --> 00:15:06,300
that's one component of the chronograph

355
00:15:10,730 --> 00:15:07,920
a second component of the chronograph

356
00:15:13,670 --> 00:15:10,740
and you see that the light disappear

357
00:15:15,350 --> 00:15:13,680
and then you can ask that it will either

358
00:15:18,889 --> 00:15:15,360
show the planet but that's not the case

359
00:15:20,629 --> 00:15:18,899
because the planet is of axis and is not

360
00:15:22,189 --> 00:15:20,639
eaten by the chronograph it's not

361
00:15:24,590 --> 00:15:22,199
blocked by the corn graph

362
00:15:26,810 --> 00:15:24,600
so there are two planets in there but we

363
00:15:29,090 --> 00:15:26,820

cannot see them because

364
00:15:31,490 --> 00:15:29,100
there are a lot of residual the yeah

365
00:15:32,990 --> 00:15:31,500
instrumental operations uh in the

366
00:15:35,990 --> 00:15:33,000
instrument that that prevent your

367
00:15:38,389 --> 00:15:36,000
chronograph to work optimally so we want

368
00:15:41,269 --> 00:15:38,399
to correct in real time

369
00:15:42,829 --> 00:15:41,279
those instrumental aberrations with a

370
00:15:46,189 --> 00:15:42,839
deformable mirror

371
00:15:48,530 --> 00:15:46,199
uh to be able to further remove the

372
00:15:51,189 --> 00:15:48,540
residual speckle or with the rule

373
00:15:55,189 --> 00:15:51,199
Starlight that we can see on the image

374
00:15:58,670 --> 00:15:55,199
and it's much I mean often not

375
00:16:00,110 --> 00:15:58,680
sufficient because we also need to use

376
00:16:02,949 --> 00:16:00,120
um and develop state-of-the-art

377
00:16:06,650 --> 00:16:02,959
processing technique to further remove

378
00:16:10,790 --> 00:16:07,990
so

379
00:16:13,250 --> 00:16:10,800
yeah I'm pretty sure that that now that

380
00:16:14,930 --> 00:16:13,260
you have

381
00:16:18,530 --> 00:16:14,940
um you know you know a little bit more

382
00:16:20,329 --> 00:16:18,540
about how the score graph works you

383
00:16:22,250 --> 00:16:20,339
would like to see what it does in

384
00:16:25,009 --> 00:16:22,260
reality I mean what a real picture of

385
00:16:30,949 --> 00:16:25,019
exoplanets so let's go to

386
00:16:34,850 --> 00:16:30,959
uh in the slide uh 11 that shows

387
00:16:36,410 --> 00:16:34,860
an actual movie not even an image an

388
00:16:38,569 --> 00:16:36,420

actual movie of

389
00:16:40,189 --> 00:16:38,579
um an orbital

390
00:16:43,189 --> 00:16:40,199
um and then a next supplementary an

391
00:16:46,910 --> 00:16:43,199
entire exoplanetary system that orbits

392
00:16:49,490 --> 00:16:46,920
the star hit HR at t799

393
00:16:52,790 --> 00:16:49,500
so I think it's

394
00:16:55,249 --> 00:16:52,800
um a particularly stunning video

395
00:16:59,509 --> 00:16:55,259
uh because this is you have to imagine

396
00:17:01,389 --> 00:16:59,519
this is a system uh that is uh at 130

397
00:17:06,409 --> 00:17:01,399
light years from us

398
00:17:10,130 --> 00:17:06,419
and the hit799 star hosts not less than

399
00:17:12,530 --> 00:17:10,140
four giant planets that are about 10

400
00:17:15,949 --> 00:17:12,540
times more massive than Jupiter

401
00:17:17,090 --> 00:17:15,959
and approximately the same diameter as

402
00:17:20,990 --> 00:17:17,100
Jupiter

403
00:17:23,329 --> 00:17:21,000
and as you can see we're pretty uh far

404
00:17:24,949 --> 00:17:23,339
from the artist's Concepts illustration

405
00:17:27,470 --> 00:17:24,959
that we are seeing all the time on the

406
00:17:29,390 --> 00:17:27,480
internet for example planets we

407
00:17:32,810 --> 00:17:29,400
currently don't have the capability to

408
00:17:33,830 --> 00:17:32,820
take such pictures but what you have in

409
00:17:36,950 --> 00:17:33,840
front of you

410
00:17:38,570 --> 00:17:36,960
um is what we can do currently in NF I

411
00:17:40,190 --> 00:17:38,580
think it's it's still pretty amazing in

412
00:17:42,289 --> 00:17:40,200
my opinion

413
00:17:43,789 --> 00:17:42,299

it is pretty amazing I could watch I

414
00:17:44,990 --> 00:17:43,799
could watch this all day as they orbit

415
00:17:47,770 --> 00:17:45,000
around

416
00:17:50,990 --> 00:17:47,780
um you talked about the star called HR

417
00:17:52,850 --> 00:17:51,000
8799 really rolls off the tongue there

418
00:17:55,010 --> 00:17:52,860
how do some of these exoplanets get

419
00:17:58,370 --> 00:17:55,020
their names

420
00:18:01,370 --> 00:17:58,380
yeah um so exoplanets

421
00:18:02,750 --> 00:18:01,380
um can have um can actually have several

422
00:18:06,710 --> 00:18:02,760
names

423
00:18:08,330 --> 00:18:06,720
so the most conventional way

424
00:18:12,350 --> 00:18:08,340
um or at least the way astronomers the

425
00:18:16,430 --> 00:18:12,360
golden exoplanet usually is by by using

426
00:18:18,549 --> 00:18:16,440
um the name of the stuff plus some minor

427
00:18:22,669 --> 00:18:18,559
case letters

428
00:18:25,190 --> 00:18:22,679
but planets are sometimes called by the

429
00:18:28,070 --> 00:18:25,200
mission that discovered them

430
00:18:30,830 --> 00:18:28,080
uh that's the case for example of the

431
00:18:34,190 --> 00:18:30,840
core Mission the Kepler Mission or the

432
00:18:36,830 --> 00:18:34,200
Trappist telescope

433
00:18:40,250 --> 00:18:36,840
um and the letters that are usually

434
00:18:42,650 --> 00:18:40,260
given by alphabetical order in in the

435
00:18:45,529 --> 00:18:42,660
order of the planet discoveries

436
00:18:47,330 --> 00:18:45,539
so let's stick the example of the

437
00:18:52,610 --> 00:18:47,340
trapeze one system on illustration

438
00:18:59,450 --> 00:18:55,789

um yeah it's the okay it's not the good

439
00:19:02,029 --> 00:18:59,460
one sorry 13 should be uh

440
00:19:04,370 --> 00:19:02,039
yeah okay yeah that there's any issue

441
00:19:07,310 --> 00:19:04,380
with the numbering anyway

442
00:19:09,230 --> 00:19:07,320
um so if we go back to the movie

443
00:19:10,870 --> 00:19:09,240
um after

444
00:19:12,890 --> 00:19:10,880
um

445
00:19:14,630 --> 00:19:12,900
exoplanetary system

446
00:19:17,390 --> 00:19:14,640
that we were showing just before yeah

447
00:19:19,270 --> 00:19:17,400
exactly this one so if we take the

448
00:19:22,909 --> 00:19:19,280
example of this movie

449
00:19:26,150 --> 00:19:22,919
uh the planet that is uh the furthest uh

450
00:19:28,789 --> 00:19:26,160
of the star is called h979b

451
00:19:32,510 --> 00:19:28,799
uh and then after the one that is a

452
00:19:34,850 --> 00:19:32,520
little bit closer is called hrt799c

453
00:19:37,850 --> 00:19:34,860
and then we have

454
00:19:41,230 --> 00:19:37,860
um HTT 799

455
00:19:45,710 --> 00:19:41,240
um D and Charities

456
00:19:47,150 --> 00:19:45,720
and and the reason uh for that is that

457
00:19:53,450 --> 00:19:47,160
the

458
00:19:54,850 --> 00:19:53,460
direct Imaging

459
00:19:57,169 --> 00:19:54,860
um because

460
00:19:59,810 --> 00:19:57,179
uh the

461
00:20:01,909 --> 00:19:59,820
better we get at developing

462
00:20:05,029 --> 00:20:01,919
post-processing technique the better we

463
00:20:08,210 --> 00:20:05,039

are and we can remove the residual

464
00:20:10,549 --> 00:20:08,220
satellites and and be able to detect

465
00:20:12,770 --> 00:20:10,559
um the the planet that are closer to the

466
00:20:15,890 --> 00:20:12,780
star but for example if we take the

467
00:20:19,430 --> 00:20:15,900
example of the Trappist one system

468
00:20:22,909 --> 00:20:19,440
um which is the one that we see we saw

469
00:20:26,330 --> 00:20:22,919
just after I think

470
00:20:30,230 --> 00:20:26,340
uh 13 or 14.

471
00:20:31,669 --> 00:20:30,240
uh should be 14 on my yeah great thank

472
00:20:35,210 --> 00:20:31,679
you

473
00:20:37,190 --> 00:20:35,220
um so this this famous exoplanetary

474
00:20:40,010 --> 00:20:37,200
system was discovered with the

475
00:20:41,289 --> 00:20:40,020
ground-based trapeze telescope using the

476
00:20:45,409 --> 00:20:41,299
transit technique

477
00:20:46,549 --> 00:20:45,419
and the first discovered planet was

478
00:20:49,669 --> 00:20:46,559
um Planet B

479
00:20:52,070 --> 00:20:49,679
uh which is the one that is closest to

480
00:20:55,070 --> 00:20:52,080
its star so it's it's different from

481
00:20:59,090 --> 00:20:55,080
what we saw just previously

482
00:21:01,610 --> 00:20:59,100
um and then comes c d e f

483
00:21:03,169 --> 00:21:01,620
um g in h that were successively

484
00:21:06,289 --> 00:21:03,179
discovered

485
00:21:07,610 --> 00:21:06,299
and the reason why the first planet to

486
00:21:08,330 --> 00:21:07,620
be discovered in the system are the

487
00:21:10,850 --> 00:21:08,340
closest

488
00:21:13,730 --> 00:21:10,860

is that they were discovered using the

489
00:21:15,590 --> 00:21:13,740
trans Transit technique as I said for

490
00:21:18,110 --> 00:21:15,600
which it is actually easier to detect

491
00:21:19,909 --> 00:21:18,120
the planet that are closest

492
00:21:22,250 --> 00:21:19,919
um and more difficult to detect the

493
00:21:24,529 --> 00:21:22,260
forever planets

494
00:21:25,850 --> 00:21:24,539
so

495
00:21:27,830 --> 00:21:25,860
yeah

496
00:21:31,370 --> 00:21:27,840
let's see

497
00:21:34,909 --> 00:21:31,380
um I think we can switch to the next

498
00:21:37,730 --> 00:21:34,919
illustration then yeah which is this one

499
00:21:41,870 --> 00:21:37,740
awesome so one thing I wanted to mention

500
00:21:44,990 --> 00:21:41,880
uh uh which is a cool thing uh is that

501
00:21:47,510 --> 00:21:45,000
the intentional astronomical Union make

502
00:21:51,110 --> 00:21:47,520
possible to the general public from the

503
00:21:55,909 --> 00:21:51,120
entire world to choose the name of a

504
00:22:00,770 --> 00:21:55,919
subset of exoplanets and uh there were a

505
00:22:04,370 --> 00:22:00,780
couple of runs in 2015 and 2019 and the

506
00:22:07,730 --> 00:22:04,380
lattice want to name exoplanets is still

507
00:22:09,350 --> 00:22:07,740
going on at the moment so if one of your

508
00:22:11,510 --> 00:22:09,360
dream has always been to name an

509
00:22:15,350 --> 00:22:11,520
exoplanet I will really suggest to go

510
00:22:16,970 --> 00:22:15,360
for it and check the website uh the name

511
00:22:20,390 --> 00:22:16,980
of the World website

512
00:22:22,909 --> 00:22:20,400
that should uh could you you could see

513
00:22:26,630 --> 00:22:22,919

you should see on your screens all right

514
00:22:28,370 --> 00:22:26,640
and and and and check that that website

515
00:22:29,690 --> 00:22:28,380
I've always wanted to name a planet

516
00:22:31,010 --> 00:22:29,700
there's all sorts of things I wanted to

517
00:22:32,390 --> 00:22:31,020
name so I'm gonna go take a look at that

518
00:22:33,649 --> 00:22:32,400
after this

519
00:22:35,529 --> 00:22:33,659
um so that's what's down the road for me

520
00:22:39,110 --> 00:22:35,539
but what's next down the road for

521
00:22:42,110 --> 00:22:39,120
exoplanet and exoplanet discovery

522
00:22:43,610 --> 00:22:42,120
yeah so next slide

523
00:22:49,789 --> 00:22:43,620
um

524
00:22:51,470 --> 00:22:49,799
the major exoplanet missions

525
00:22:54,230 --> 00:22:51,480
um so the best current and future

526
00:22:56,270 --> 00:22:54,240
missions and if you look at the the top

527
00:22:58,549 --> 00:22:56,280
right you will see

528
00:23:01,669 --> 00:22:58,559
um a space telescope that has been

529
00:23:03,529 --> 00:23:01,679
recently launched and commissioned

530
00:23:06,110 --> 00:23:03,539
um the James Webb Space Telescope or

531
00:23:09,169 --> 00:23:06,120
jwst

532
00:23:12,409 --> 00:23:09,179
um and after Jetta breast T

533
00:23:14,630 --> 00:23:12,419
um the next Underworld will be the Nancy

534
00:23:16,850 --> 00:23:14,640
Grace romance based telescope

535
00:23:19,850 --> 00:23:16,860
a Hubble size telescope that will be

536
00:23:22,310 --> 00:23:19,860
launched in 2026 and that will cover

537
00:23:26,450 --> 00:23:22,320
some great exoplanet topics

538
00:23:29,870 --> 00:23:26,460

so let's dive a bit more we what's

539
00:23:31,549 --> 00:23:29,880
coming in the next 10 years

540
00:23:32,570 --> 00:23:31,559
so next slide

541
00:23:36,409 --> 00:23:32,580
um

542
00:23:38,710 --> 00:23:36,419
how not to mention the first exoplanet

543
00:23:42,590 --> 00:23:38,720
image with James Webb

544
00:23:45,649 --> 00:23:42,600
and this has been recently made uh right

545
00:23:46,789 --> 00:23:45,659
that there are image um as of the

546
00:23:47,450 --> 00:23:46,799
planets

547
00:23:48,730 --> 00:23:47,460
um

548
00:23:54,110 --> 00:23:48,740
hap

549
00:23:58,130 --> 00:23:54,120
65 426 B that was released about two

550
00:24:01,310 --> 00:23:58,140
months ago uh so this this planet is a

551
00:24:05,810 --> 00:24:01,320
nine Jupiter um

552
00:24:13,010 --> 00:24:08,529
um that is at

553
00:24:16,990 --> 00:24:13,020
385 light years from Earth

554
00:24:23,810 --> 00:24:20,570
2017 with the sphere instruments on the

555
00:24:26,510 --> 00:24:23,820
VLT and this planet was chosen to be a

556
00:24:28,789 --> 00:24:26,520
prime target for James Webb because it

557
00:24:31,669 --> 00:24:28,799
is at wide separation of its style and

558
00:24:35,090 --> 00:24:31,679
that's pretty easy to spot uh with JBC

559
00:24:38,330 --> 00:24:35,100
but um we expect jwc will discover new

560
00:24:39,649 --> 00:24:38,340
exoplanet by by dozen pretty soon

561
00:24:44,450 --> 00:24:39,659
and

562
00:24:48,590 --> 00:24:46,070
we can see

563
00:24:51,289 --> 00:24:48,600

um an example of of Target that we will

564
00:24:55,510 --> 00:24:51,299
uh observe with James web and you can

565
00:24:58,610 --> 00:24:55,520
recognize uh the hrt799 system

566
00:25:01,190 --> 00:24:58,620
that we talked about earlier

567
00:25:05,390 --> 00:25:01,200
so we will observe that Target very soon

568
00:25:08,750 --> 00:25:05,400
with James web and we will not only

569
00:25:10,669 --> 00:25:08,760
um further characterize uh the exoplanet

570
00:25:12,590 --> 00:25:10,679
the Forex the planet that are in that

571
00:25:16,190 --> 00:25:12,600
system with those observations but we

572
00:25:20,630 --> 00:25:16,200
also will look for new planets in this

573
00:25:23,450 --> 00:25:20,640
system and there will be also many other

574
00:25:27,070 --> 00:25:23,460
systems that will be observed as well

575
00:25:29,570 --> 00:25:27,080
so we don't expect uh James Webb to find

576
00:25:32,269 --> 00:25:29,580
thousands of exoplanet like like

577
00:25:35,090 --> 00:25:32,279
previous missions of such as Kepler or

578
00:25:38,029 --> 00:25:35,100
Tess because the stethoscope is not

579
00:25:40,549 --> 00:25:38,039
dedicated to exoplanet science

580
00:25:43,669 --> 00:25:40,559
um JVC is going to do a lot of other

581
00:25:45,830 --> 00:25:43,679
great science besides exoplanets even if

582
00:25:48,470 --> 00:25:45,840
maybe we can expect that 25 percent of

583
00:25:51,049 --> 00:25:48,480
jwc time may be

584
00:25:52,909 --> 00:25:51,059
um on exoplanet science but we expect

585
00:25:55,370 --> 00:25:52,919
great discoveries in the field of

586
00:25:57,830 --> 00:25:55,380
exoplanet characterization like

587
00:26:00,370 --> 00:25:57,840
illustration uh the next illustration is

588
00:26:06,289 --> 00:26:04,430

so oh okay it's sorry it's not this one

589
00:26:06,950 --> 00:26:06,299
should be the spectrum of

590
00:26:09,470 --> 00:26:06,960
um

591
00:26:13,250 --> 00:26:09,480
James Webb

592
00:26:14,630 --> 00:26:13,260
I think I have it 19.

593
00:26:17,269 --> 00:26:14,640
yep

594
00:26:19,490 --> 00:26:17,279
excellent thank you

595
00:26:20,990 --> 00:26:19,500
um so

596
00:26:26,149 --> 00:26:21,000
this

597
00:26:32,990 --> 00:26:26,159
um

598
00:26:35,950 --> 00:26:33,000
is called wasp uh 96 B

599
00:26:39,830 --> 00:26:35,960
which is a hot gas giant exoplanet

600
00:26:44,269 --> 00:26:39,840
and it has half the size of Jupiter and

601
00:26:47,830 --> 00:26:44,279
it orbits it starts every 3.4 days

602
00:26:51,169 --> 00:26:47,840
um and is it's located at uh

603
00:26:52,490 --> 00:26:51,179
1150 light years from us

604
00:26:55,850 --> 00:26:52,500
and

605
00:26:58,690 --> 00:26:55,860
um jdbst was actually able to detect

606
00:27:02,149 --> 00:26:58,700
water in the atmosphere of this planet

607
00:27:04,970 --> 00:27:02,159
which was a Ponte quite unexpected for

608
00:27:08,029 --> 00:27:04,980
that particular object because

609
00:27:10,370 --> 00:27:08,039
um it was previously thought to be

610
00:27:14,350 --> 00:27:10,380
cloudless completely cloudless so so it

611
00:27:17,990 --> 00:27:14,360
was quite a surprise and JVC will probe

612
00:27:20,510 --> 00:27:18,000
the atmosphere composition of many known

613
00:27:23,269 --> 00:27:20,520

planets to identify chemical components

614
00:27:24,409 --> 00:27:23,279
such as water methane or carbon dioxide

615
00:27:27,409 --> 00:27:24,419
dioxide

616
00:27:29,930 --> 00:27:27,419
and uh it's gonna do that with a lot of

617
00:27:32,169 --> 00:27:29,940
non-exoplanets and it really opened the

618
00:27:35,210 --> 00:27:32,179
path to uh statistics

619
00:27:36,529 --> 00:27:35,220
statistical analysis of those uh

620
00:27:38,870 --> 00:27:36,539
exoplanets

621
00:27:42,049 --> 00:27:38,880
and um so we with this capability

622
00:27:44,090 --> 00:27:42,059
capability we hope to learn more about

623
00:27:46,250 --> 00:27:44,100
the composition of exoplane atmospheres

624
00:27:49,190 --> 00:27:46,260
and and then how they form they were

625
00:27:52,490 --> 00:27:49,200
formed and also learn more about uh the

626
00:27:55,549 --> 00:27:52,500
planet in our own solar system as well

627
00:27:57,230 --> 00:27:55,559
James Webb is is kind of it's astounding

628
00:27:58,669 --> 00:27:57,240
and the images and everything we find

629
00:28:00,230 --> 00:27:58,679
from that but I want to talk about what

630
00:28:02,210 --> 00:28:00,240
you're going to be working on

631
00:28:03,649 --> 00:28:02,220
um the Nancy Grace Roman Space Telescope

632
00:28:07,010 --> 00:28:03,659
can you tell us more about that with

633
00:28:08,930 --> 00:28:07,020
this field yes yes of course so yeah

634
00:28:12,490 --> 00:28:08,940
next slide should be the Roman space to

635
00:28:16,970 --> 00:28:12,500
this cup slide yep awesome so

636
00:28:20,149 --> 00:28:16,980
Roman is the next big NASA mission to be

637
00:28:23,570 --> 00:28:20,159
launched in 2026 with two different

638
00:28:26,149 --> 00:28:23,580

instruments so first we have we have a

639
00:28:27,230 --> 00:28:26,159
science instrument which is called the

640
00:28:30,169 --> 00:28:27,240
Whitefield

641
00:28:32,990 --> 00:28:30,179
um imager that will detect thousands of

642
00:28:37,430 --> 00:28:33,000
new exoplanets using the techniques of

643
00:28:40,669 --> 00:28:37,440
transits and microlensing and second we

644
00:28:43,549 --> 00:28:40,679
will have a technology demonstrator uh

645
00:28:45,649 --> 00:28:43,559
the chronograph instruments uh that will

646
00:28:48,769 --> 00:28:45,659
demonstrate the key technologies that we

647
00:28:50,210 --> 00:28:48,779
need to image terrestrial planets in the

648
00:28:51,950 --> 00:28:50,220
habitable zone of the star and

649
00:28:55,310 --> 00:28:51,960
characterize the Spectra

650
00:28:58,250 --> 00:28:55,320
so you can see for example

651
00:29:01,310 --> 00:28:58,260
um one image simulated image of of what

652
00:29:03,669 --> 00:29:01,320
we we could see uh you might you might

653
00:29:06,230 --> 00:29:03,679
think okay it's it's not

654
00:29:09,049 --> 00:29:06,240
it doesn't seem better than what we saw

655
00:29:11,930 --> 00:29:09,059
already but there is actually a big

656
00:29:14,630 --> 00:29:11,940
difference is uh the the contrast that

657
00:29:17,269 --> 00:29:14,640
we were able to reach with Roman is

658
00:29:18,889 --> 00:29:17,279
several order of magnitudes the contrast

659
00:29:21,049 --> 00:29:18,899
that we are able to reach right now with

660
00:29:22,970 --> 00:29:21,059
the current instruments so with the

661
00:29:27,590 --> 00:29:22,980
current instrument we can do contrast of

662
00:29:29,750 --> 00:29:27,600
ten tournaments six for example are but

663
00:29:31,610 --> 00:29:29,760

but here we're gonna be with Roman we're

664
00:29:33,529 --> 00:29:31,620
going to be able to observe planets with

665
00:29:37,010 --> 00:29:33,539
contrast to 10 to the minus nine

666
00:29:38,810 --> 00:29:37,020
and and that's um hold this while the

667
00:29:42,769 --> 00:29:38,820
demonstrating the technologies that that

668
00:29:45,409 --> 00:29:42,779
we will uh use to uh further I mean to

669
00:29:48,049 --> 00:29:45,419
detect territory planets

670
00:29:51,289 --> 00:29:48,059
um using direct Imaging in the future so

671
00:29:55,070 --> 00:29:51,299
it is the next slide will show that that

672
00:29:56,870 --> 00:29:55,080
this romantic scope will open the path

673
00:29:59,330 --> 00:29:56,880
to the next generation of space-based

674
00:30:02,149 --> 00:29:59,340
telescope that will look for signs of

675
00:30:04,010 --> 00:30:02,159
Life on exoplanets

676
00:30:06,950 --> 00:30:04,020
um but for those telescopes will be

677
00:30:09,049 --> 00:30:06,960
become reality uh there's still a lot of

678
00:30:11,389 --> 00:30:09,059
a lot of work to go uh and we'll have to

679
00:30:13,010 --> 00:30:11,399
be patient and with at least uh 20 years

680
00:30:14,810 --> 00:30:13,020
or more

681
00:30:16,370 --> 00:30:14,820
that's that's amazing and it's

682
00:30:17,810 --> 00:30:16,380
astounding and I'm looking forward to

683
00:30:20,750 --> 00:30:17,820
everything that you find with that

684
00:30:23,269 --> 00:30:20,760
telescope the audience have been asking

685
00:30:24,830 --> 00:30:23,279
amazing questions tonight so I'm gonna

686
00:30:26,630 --> 00:30:24,840
throw it over to Nora and let's get

687
00:30:28,789 --> 00:30:26,640
these audience questions in our in our

688
00:30:30,590 --> 00:30:28,799

talk tonight

689
00:30:32,029 --> 00:30:30,600
yeah thanks Brian this was a great talk

690
00:30:34,070 --> 00:30:32,039
and there have been so many awesome

691
00:30:35,990 --> 00:30:34,080
questions from our audience

692
00:30:37,549 --> 00:30:36,000
um so Cyclops on Twitter asks is there

693
00:30:41,049 --> 00:30:37,559
anything in the works to send a

694
00:30:44,690 --> 00:30:41,059
spacecraft to any of these exoplanets

695
00:30:48,049 --> 00:30:44,700
yeah um I I've heard about some some

696
00:30:51,590 --> 00:30:48,059
projects uh that that could visit some

697
00:30:54,710 --> 00:30:51,600
of the um uh planets that are uh the

698
00:30:58,070 --> 00:30:54,720
closest to us so the planets in um in

699
00:31:01,190 --> 00:30:58,080
the Proxima Century uh system uh which

700
00:31:03,370 --> 00:31:01,200
is the star which is uh our neighborhood

701
00:31:07,610 --> 00:31:03,380
basically the star that is closest to us

702
00:31:11,510 --> 00:31:07,620
however it's a star that is located at

703
00:31:14,389 --> 00:31:11,520
um free uh three to four uh yeah uh

704
00:31:18,110 --> 00:31:14,399
light year so that that means that if we

705
00:31:19,330 --> 00:31:18,120
were to go to that star the speed of

706
00:31:22,370 --> 00:31:19,340
light

707
00:31:24,590 --> 00:31:22,380
we we it will take us

708
00:31:27,230 --> 00:31:24,600
um three to four years to go there but

709
00:31:29,870 --> 00:31:27,240
but we are pretty far to to go at that

710
00:31:32,990 --> 00:31:29,880
at that speed and so

711
00:31:35,450 --> 00:31:33,000
um uh it's it's for for now uh a little

712
00:31:36,769 --> 00:31:35,460
bit Out Of Reach uh but there are

713
00:31:38,930 --> 00:31:36,779

definitely some some you know some

714
00:31:40,850 --> 00:31:38,940
projects uh and people are thinking

715
00:31:43,130 --> 00:31:40,860
about that because it's it's like a fun

716
00:31:46,490 --> 00:31:43,140
thing to think about visiting a another

717
00:31:50,210 --> 00:31:48,649
yeah uh Donny on LinkedIn actually asked

718
00:31:52,130 --> 00:31:50,220
would we ever assign humans not just

719
00:31:53,450 --> 00:31:52,140
spacecraft do you think with if we had

720
00:31:55,549 --> 00:31:53,460
the advanced technology would we be able

721
00:32:00,110 --> 00:31:55,559
to send humans there as well

722
00:32:03,289 --> 00:32:00,120
yeah so so kind of the same answer here

723
00:32:06,470 --> 00:32:03,299
is that we don't have the the technology

724
00:32:08,870 --> 00:32:06,480
for now to to even send a spectraf so

725
00:32:12,049 --> 00:32:08,880
I'm pretty sure if if the if we had the

726
00:32:14,810 --> 00:32:12,059
technology to to to go

727
00:32:17,389 --> 00:32:14,820
um people some people would like to go

728
00:32:19,789 --> 00:32:17,399
um but yeah it's it's definitely it's

729
00:32:22,909 --> 00:32:19,799
already a challenge to go to Mars right

730
00:32:24,529 --> 00:32:22,919
or even to go back to the moon so

731
00:32:28,010 --> 00:32:24,539
um yeah it's definitely not the same

732
00:32:31,310 --> 00:32:28,020
distance so uh yeah it it's it's not far

733
00:32:33,889 --> 00:32:31,320
for tomorrow and then people in in our

734
00:32:37,730 --> 00:32:33,899
generation is and or we're not gonna see

735
00:32:39,710 --> 00:32:37,740
that uh in you know lifetime yeah it'd

736
00:32:41,570 --> 00:32:39,720
be a long trip

737
00:32:43,130 --> 00:32:41,580
so Vector on YouTube asked about the

738
00:32:45,230 --> 00:32:43,140

trappist-1 system that you were talking

739
00:32:47,090 --> 00:32:45,240
about uh is it possible that there are

740
00:32:48,950 --> 00:32:47,100
planets that are either really small or

741
00:32:50,389 --> 00:32:48,960
on tilted orbits that exist in that

742
00:32:53,330 --> 00:32:50,399
system and we just don't know about them

743
00:32:55,909 --> 00:32:53,340
because they haven't transited

744
00:32:58,490 --> 00:32:55,919
yeah yeah it's totally possible I mean

745
00:33:00,950 --> 00:32:58,500
anything can be possible

746
00:33:02,389 --> 00:33:00,960
um it's possible that there are some you

747
00:33:05,169 --> 00:33:02,399
know

748
00:33:07,850 --> 00:33:05,179
um gravitational interaction in a system

749
00:33:12,590 --> 00:33:07,860
between some some planets that that

750
00:33:15,950 --> 00:33:12,600
makes a planet change orbits and

751
00:33:17,990 --> 00:33:15,960
um and and have an inclined orbits that

752
00:33:19,610 --> 00:33:18,000
that will be possible

753
00:33:22,190 --> 00:33:19,620
um but but we don't yeah we don't know

754
00:33:26,210 --> 00:33:22,200
and and that's one of the advantage to

755
00:33:29,870 --> 00:33:26,220
you use several techniques to observe

756
00:33:31,909 --> 00:33:29,880
same system because because because they

757
00:33:34,130 --> 00:33:31,919
are complementary right so if we don't

758
00:33:36,830 --> 00:33:34,140
detect with the transits because they

759
00:33:37,750 --> 00:33:36,840
are not in the the same you know same

760
00:33:44,330 --> 00:33:37,760
plane

761
00:33:46,669 --> 00:33:44,340
system using the radial velocity

762
00:33:48,590 --> 00:33:46,679
technique or even direct Imaging if we

763
00:33:50,570 --> 00:33:48,600

are looking but the the Trappist system

764
00:33:52,610 --> 00:33:50,580
is a little bit far too to be accessible

765
00:33:56,750 --> 00:33:52,620
for for direct Imaging but who knows

766
00:34:02,450 --> 00:34:00,049
awesome uh zaker on LinkedIn as well as

767
00:34:04,250 --> 00:34:02,460
Cyclops on Twitter both asked about um

768
00:34:06,470 --> 00:34:04,260
how we actually identify the chemical

769
00:34:08,450 --> 00:34:06,480
chemical composition of these exoplanets

770
00:34:10,190 --> 00:34:08,460
like you were showing with the um jwst

771
00:34:13,849 --> 00:34:10,200
Spectra

772
00:34:16,849 --> 00:34:13,859
yeah that's a great question so to do

773
00:34:18,950 --> 00:34:16,859
that we have uh two techniques

774
00:34:22,609 --> 00:34:18,960
um so the first the first one is to

775
00:34:24,589 --> 00:34:22,619
observe uh the same uh system using

776
00:34:27,589 --> 00:34:24,599
different filters at different

777
00:34:31,250 --> 00:34:27,599
wavelengths so that gives us some clues

778
00:34:32,450 --> 00:34:31,260
about uh the composition of uh the those

779
00:34:35,089 --> 00:34:32,460
planets so that's something that we're

780
00:34:37,089 --> 00:34:35,099
going to do on James Webb uh using uh

781
00:34:39,490 --> 00:34:37,099
for example nunyakam or the Miri

782
00:34:44,329 --> 00:34:39,500
chronograph that we have on James web

783
00:34:48,530 --> 00:34:44,339
but we don't have the capability to do a

784
00:34:50,869 --> 00:34:48,540
spectrum using direct Imaging because we

785
00:34:53,930 --> 00:34:50,879
don't have a prism on the the instrument

786
00:34:56,089 --> 00:34:53,940
that have the chronograph we have some

787
00:34:59,170 --> 00:34:56,099
some spectrograph

788
00:35:02,329 --> 00:34:59,180

which are kind of prism

789
00:35:05,390 --> 00:35:02,339
elaborate elaborated prism on on

790
00:35:08,930 --> 00:35:05,400
instruments that uh that we are using to

791
00:35:11,930 --> 00:35:08,940
uh disperse the light that will receive

792
00:35:14,089 --> 00:35:11,940
from a planet or Star to create those

793
00:35:16,190 --> 00:35:14,099
spectrums so this is how we create those

794
00:35:16,970 --> 00:35:16,200
pictures so here as you can see on the

795
00:35:18,890 --> 00:35:16,980
top

796
00:35:21,230 --> 00:35:18,900
um right the Spectrum has been done

797
00:35:23,630 --> 00:35:21,240
using uh the in the nearest instrument

798
00:35:26,510 --> 00:35:23,640
on James web

799
00:35:29,569 --> 00:35:26,520
um and and this has been done using uh

800
00:35:30,650 --> 00:35:29,579
the transit technique in particular on

801
00:35:32,210 --> 00:35:30,660
Roman

802
00:35:34,730 --> 00:35:32,220
it's going to be a little bit different

803
00:35:37,670 --> 00:35:34,740
is that we're gonna combine a

804
00:35:39,829 --> 00:35:37,680
chronograph and a spectrograph so that

805
00:35:41,810 --> 00:35:39,839
we will be able to not only do some

806
00:35:45,290 --> 00:35:41,820
direct Imaging and and see pictures of

807
00:35:48,650 --> 00:35:45,300
those planets but also we will

808
00:35:51,470 --> 00:35:48,660
um be we will have the capability to

809
00:35:54,170 --> 00:35:51,480
um to take those pictures and and put

810
00:35:56,690 --> 00:35:54,180
that there's put them in a spectrograph

811
00:35:58,970 --> 00:35:56,700
and also extract

812
00:36:00,470 --> 00:35:58,980
um the Spectrum from from that style so

813
00:36:02,030 --> 00:36:00,480

this is why this technology

814
00:36:03,710 --> 00:36:02,040
demonstration is so important because

815
00:36:06,349 --> 00:36:03,720
combining the chronograph into

816
00:36:08,750 --> 00:36:06,359
spectrograph uh will give us the the

817
00:36:10,490 --> 00:36:08,760
capability to to Really

818
00:36:12,589 --> 00:36:10,500
um observe

819
00:36:16,010 --> 00:36:12,599
um and and characterize uh the the

820
00:36:17,630 --> 00:36:16,020
atmosphere of those planets

821
00:36:20,450 --> 00:36:17,640
thanks that's really exciting really

822
00:36:21,890 --> 00:36:20,460
looking forward to Roman uh so Tom on

823
00:36:23,630 --> 00:36:21,900
LinkedIn asked if there's any kind of

824
00:36:25,370 --> 00:36:23,640
special exoplanet science that can

825
00:36:30,050 --> 00:36:25,380
actually be done um taking advantage of

826
00:36:35,089 --> 00:36:32,690
oh and one oh and two maybe you know

827
00:36:39,410 --> 00:36:35,099
whenever

828
00:36:42,349 --> 00:36:39,420
um yeah I mean all exoplanets uh science

829
00:36:43,390 --> 00:36:42,359
um can take advantage of of being at

830
00:36:47,930 --> 00:36:43,400
that point

831
00:36:48,849 --> 00:36:47,940
because those those kind of points are

832
00:36:52,730 --> 00:36:48,859
um

833
00:36:54,470 --> 00:36:52,740
gravitationally stable point in space uh

834
00:36:56,750 --> 00:36:54,480
that that offer

835
00:37:00,530 --> 00:36:56,760
um much stable condition

836
00:37:02,569 --> 00:37:00,540
for observation and so when we observe

837
00:37:04,069 --> 00:37:02,579
exoplanets with any kind of technique

838
00:37:06,950 --> 00:37:04,079

basically

839
00:37:10,370 --> 00:37:06,960
um the more stable telescope is the

840
00:37:13,190 --> 00:37:10,380
better right uh so that's one thing

841
00:37:15,829 --> 00:37:13,200
um and and and if we want to increase

842
00:37:18,890 --> 00:37:15,839
the the detection capabilities we want

843
00:37:21,410 --> 00:37:18,900
to spend more and more time on on those

844
00:37:22,970 --> 00:37:21,420
planets so we want to be as stable as

845
00:37:25,430 --> 00:37:22,980
possible because you're gonna stay alone

846
00:37:28,069 --> 00:37:25,440
for a long time on those planets and and

847
00:37:32,050 --> 00:37:28,079
the second uh great advantage of going

848
00:37:35,510 --> 00:37:32,060
uh to L2 for example such as

849
00:37:39,530 --> 00:37:35,520
that L2 Roman will be at L2 as well

850
00:37:43,370 --> 00:37:39,540
is that we um uh the telescope is going

851
00:37:44,569 --> 00:37:43,380
to be further from uh the earth and the

852
00:37:47,750 --> 00:37:44,579
f is

853
00:37:50,329 --> 00:37:47,760
um kind of a black body uh that that

854
00:37:51,890 --> 00:37:50,339
that's gonna emit a lot of infrared

855
00:37:55,630 --> 00:37:51,900
lights

856
00:37:58,250 --> 00:37:55,640
um and this is also for example the

857
00:37:59,690 --> 00:37:58,260
wavelength in which uh James Webb

858
00:38:03,530 --> 00:37:59,700
observes

859
00:38:07,310 --> 00:38:03,540
right and uh so you don't want I mean

860
00:38:09,770 --> 00:38:07,320
the the Earth is pretty bright for James

861
00:38:12,410 --> 00:38:09,780
Webb uh because it's observing in the

862
00:38:16,250 --> 00:38:12,420
same wavelength that the Earth is um

863
00:38:18,230 --> 00:38:16,260

emitting so the further you are from the

864
00:38:20,270 --> 00:38:18,240
the earth and the better it is for for

865
00:38:23,930 --> 00:38:20,280
example science in particular in

866
00:38:28,849 --> 00:38:27,109
awesome uh so Syringa on LinkedIn asked

867
00:38:31,490 --> 00:38:28,859
out of all of the exoplanets discovered

868
00:38:33,530 --> 00:38:31,500
so far how many closely resemble Earth

869
00:38:35,150 --> 00:38:33,540
in terms of atmosphere and land or even

870
00:38:38,089 --> 00:38:35,160
water

871
00:38:39,770 --> 00:38:38,099
yeah

872
00:38:45,230 --> 00:38:39,780
um

873
00:38:47,750 --> 00:38:45,240
say that that that we will look looking

874
00:38:51,230 --> 00:38:47,760
into and so first we you need to have a

875
00:38:54,109 --> 00:38:51,240
terrestrial planets a rocky planet uh to

876
00:38:56,450 --> 00:38:54,119
be close uh similar to the Earth so

877
00:38:59,089 --> 00:38:56,460
that's one thing the second thing is uh

878
00:39:03,650 --> 00:38:59,099
you have to have an atmosphere

879
00:39:05,870 --> 00:39:03,660
um and um and the third thing is that if

880
00:39:07,790 --> 00:39:05,880
we want to uh to find something similar

881
00:39:11,750 --> 00:39:07,800
to the Earth we want to find a planet

882
00:39:13,970 --> 00:39:11,760
that is located in the habitable zone of

883
00:39:18,950 --> 00:39:13,980
its star so that means that this is a

884
00:39:20,089 --> 00:39:18,960
Zone uh where uh water can exist in

885
00:39:23,270 --> 00:39:20,099
liquid form

886
00:39:25,790 --> 00:39:23,280
and that could be very

887
00:39:28,790 --> 00:39:25,800
um some very conditions for the the life

888
00:39:32,030 --> 00:39:28,800

to uh develop in such a such a such a

889
00:39:34,069 --> 00:39:32,040
planet so so for now we know that there

890
00:39:37,730 --> 00:39:34,079
are some terrestrial planets that exist

891
00:39:39,410 --> 00:39:37,740
in the double zone of Their Stars uh but

892
00:39:41,510 --> 00:39:39,420
we still don't know if those particular

893
00:39:43,609 --> 00:39:41,520
planets and there are a couple of them

894
00:39:45,290 --> 00:39:43,619
they're not many many but there are a

895
00:39:46,790 --> 00:39:45,300
couple of them we know about a couple of

896
00:39:48,829 --> 00:39:46,800
them and

897
00:39:52,069 --> 00:39:48,839
um we don't know yet if those particular

898
00:39:55,670 --> 00:39:52,079
planets have an atmosphere still

899
00:39:58,790 --> 00:39:55,680
um and so that's that's one of the uh

900
00:40:01,130 --> 00:39:58,800
the thing the one of the uh the

901
00:40:03,230 --> 00:40:01,140
questions that that James Webb will up

902
00:40:05,150 --> 00:40:03,240
to answer actually by by pointing some

903
00:40:07,670 --> 00:40:05,160
of the the planets that are in the

904
00:40:09,410 --> 00:40:07,680
trapeze one system uh that are pretty

905
00:40:13,730 --> 00:40:09,420
good candidates for that

906
00:40:15,530 --> 00:40:13,740
so so we'll done more with Jim's web

907
00:40:16,970 --> 00:40:15,540
that's really exciting it's one thing I

908
00:40:18,890 --> 00:40:16,980
love about exoplanet science is there's

909
00:40:20,329 --> 00:40:18,900
just so much left to learn so we just

910
00:40:21,770 --> 00:40:20,339
have time for one last question I think

911
00:40:24,230 --> 00:40:21,780
this will be a great one to end on this

912
00:40:25,490 --> 00:40:24,240
is from Anaya on YouTube and she asks

913
00:40:27,050 --> 00:40:25,500

how did you know you wanted to study

914
00:40:28,670 --> 00:40:27,060
this topic and what tips would you have

915
00:40:31,670 --> 00:40:28,680
for a younger person or anyone who's

916
00:40:35,329 --> 00:40:31,680
interested in astronomy and astrophysics

917
00:40:36,950 --> 00:40:35,339
yeah that's a great one so I'm I always

918
00:40:40,069 --> 00:40:36,960
been

919
00:40:42,890 --> 00:40:40,079
um obsessed kind of by astronomy when I

920
00:40:46,190 --> 00:40:42,900
was uh like super young I was always

921
00:40:49,670 --> 00:40:46,200
looking for the moon and so I kind of

922
00:40:53,030 --> 00:40:49,680
knew I mean that that I liked it

923
00:40:56,569 --> 00:40:53,040
um but I didn't know that I it could be

924
00:40:59,210 --> 00:40:56,579
like a job right and so I discovered

925
00:41:03,050 --> 00:40:59,220
that when I was a team uh reading

926
00:41:04,490 --> 00:41:03,060
reading a you know Science magazine and

927
00:41:05,690 --> 00:41:04,500
um I discovered that that you could

928
00:41:09,050 --> 00:41:05,700
actually

929
00:41:12,589 --> 00:41:09,060
um be an astronomer and study uh this uh

930
00:41:15,650 --> 00:41:12,599
as a job and uh that day I figured that

931
00:41:17,990 --> 00:41:15,660
that's what I wanted to do right and I

932
00:41:20,210 --> 00:41:18,000
didn't know that I would wanted to to

933
00:41:24,290 --> 00:41:20,220
work on exoplanets because at the time

934
00:41:25,609 --> 00:41:24,300
we hadn't uh yeah I'm that old at that

935
00:41:27,290 --> 00:41:25,619
time I didn't

936
00:41:28,250 --> 00:41:27,300
um we didn't know that that exoplanet

937
00:41:33,650 --> 00:41:28,260
existed

938
00:41:37,010 --> 00:41:33,660

and uh so I I was yeah lucky uh to to to

939
00:41:39,170 --> 00:41:37,020
be here I mean to be around when when

940
00:41:40,970 --> 00:41:39,180
um and and pretty I mean that young when

941
00:41:42,829 --> 00:41:40,980
when uh we discovered the first

942
00:41:45,470 --> 00:41:42,839
exoplanet and so I followed all that

943
00:41:48,410 --> 00:41:45,480
that stuff and I had the opportunity

944
00:41:51,349 --> 00:41:48,420
when I was a student

945
00:41:53,510 --> 00:41:51,359
um to do an internship at the uh

946
00:41:55,010 --> 00:41:53,520
Observatory the the party so it wasn't

947
00:41:56,750 --> 00:41:55,020
friends

948
00:42:00,410 --> 00:41:56,760
um and uh this internship was in

949
00:42:03,589 --> 00:42:00,420
exoplanets and uh since that that uh

950
00:42:05,810 --> 00:42:03,599
that day I um I knew that I wanted to be

951
00:42:08,750 --> 00:42:05,820
in a swimmer I didn't know uh I didn't

952
00:42:10,790 --> 00:42:08,760
knew what I didn't know what kind of

953
00:42:13,010 --> 00:42:10,800
instrument I wanted I wanted wanted to

954
00:42:15,650 --> 00:42:13,020
be but that day I just I I said okay the

955
00:42:18,170 --> 00:42:15,660
planet is so cool I just want to to be

956
00:42:19,790 --> 00:42:18,180
validate and and to to answer that

957
00:42:20,630 --> 00:42:19,800
that's a good question but is there any

958
00:42:24,530 --> 00:42:20,640
tips

959
00:42:27,829 --> 00:42:24,540
um I'd say one of them maybe the best

960
00:42:31,670 --> 00:42:27,839
tip I would I would I would give is that

961
00:42:34,310 --> 00:42:31,680
if you know you want to do something and

962
00:42:37,250 --> 00:42:34,320
you're really passionate about it uh and

963
00:42:39,230 --> 00:42:37,260

it's you know part of you kind of you

964
00:42:40,490 --> 00:42:39,240
should really persevere because it's

965
00:42:42,710 --> 00:42:40,500
very hard

966
00:42:46,250 --> 00:42:42,720
um there are a lot of obstacles

967
00:42:49,849 --> 00:42:46,260
um and it's only by by you know

968
00:42:52,010 --> 00:42:49,859
pressuring uh that uh that you can reach

969
00:42:54,349 --> 00:42:52,020
those goals and and be able to do what

970
00:42:57,650 --> 00:42:54,359
what you want to do

971
00:42:58,849 --> 00:42:57,660
that is a perfect way to end tonight

972
00:43:00,770 --> 00:42:58,859
um unfortunately everyone that is all

973
00:43:02,809 --> 00:43:00,780
the time we have for this evening I do

974
00:43:05,210 --> 00:43:02,819
want to thank our co-host Dr Nora Bailey

975
00:43:07,750 --> 00:43:05,220
and our terrific speaker Marie Dr Murray

976
00:43:11,450 --> 00:43:07,760
igoo for their joy and their expertise

977
00:43:14,329 --> 00:43:11,460
we also wanted that Christopher Colin

978
00:43:16,910 --> 00:43:14,339
Max Bill Gabby Mark Curtis Nikki Jillian

979
00:43:18,470 --> 00:43:16,920
everyone everyone that you don't see but

980
00:43:20,930 --> 00:43:18,480
they're there monthly behind the scenes

981
00:43:23,270 --> 00:43:20,940
who make these public talks possible our

982
00:43:26,690 --> 00:43:23,280
final thank you is to you the audience

983
00:43:29,329 --> 00:43:26,700
who join us every single month this is

984
00:43:31,130 --> 00:43:29,339
your space program and we're grateful

985
00:43:33,589 --> 00:43:31,140
you invite us into your lives every

986
00:43:35,990 --> 00:43:33,599
month with these Von Carmen talks our

987
00:43:38,630 --> 00:43:36,000
next talk will be in January of 2023.

988
00:43:42,230 --> 00:43:38,640

thank you again to our speakers stay