



1
00:00:00,790 --> 00:00:07,320

[Music]

2
00:00:11,549 --> 00:00:09,259

[Applause]

3
00:00:14,430 --> 00:00:11,559

welcome to the exoplanets plenary

4
00:00:16,350 --> 00:00:14,440

session at apps icon today I'm Carl stop

5
00:00:17,609 --> 00:00:16,360

Oh felt from the exoplanet exploration

6
00:00:20,220 --> 00:00:17,619

program office at the Jet Propulsion

7
00:00:22,140 --> 00:00:20,230

Laboratory my co-chair this morning is

8
00:00:24,960 --> 00:00:22,150

Sean Domino Goldman here from the

9
00:00:26,550 --> 00:00:24,970

Goddard Space Flight Center so as you

10
00:00:28,200 --> 00:00:26,560

saw from yesterday's sessions and I

11
00:00:30,839 --> 00:00:28,210

think you're gonna see a lot more during

12
00:00:32,370 --> 00:00:30,849

today's session a remote telescopic

13
00:00:34,590 --> 00:00:32,380

study of exoplanets and their

14

00:00:36,479 --> 00:00:34,600

environments is a really major way we

15

00:00:38,880 --> 00:00:36,489

can advance the science of astrobiology

16

00:00:40,950 --> 00:00:38,890

and we can go beyond just the limited

17

00:00:43,229 --> 00:00:40,960

number of settings in our own solar

18

00:00:45,930 --> 00:00:43,239

system for this we can go to a full

19

00:00:49,110 --> 00:00:45,940

universe galaxy of planets which now has

20

00:00:53,040 --> 00:00:49,120

past 4,000 that have been confirmed by a

21

00:00:55,020 --> 00:00:53,050

number of methods so the pace of that is

22

00:00:56,630 --> 00:00:55,030

doubling every two and a half years so

23

00:01:00,389 --> 00:00:56,640

there's a very bright future for

24

00:01:04,619 --> 00:01:00,399

astrobiology in exoplanets so the

25

00:01:06,510 --> 00:01:04,629

missions that take place in NASA and

26

00:01:08,160 --> 00:01:06,520

European Space Agency's that that are

27

00:01:10,290 --> 00:01:08,170

related to exoplanets are shown on this

28

00:01:12,060 --> 00:01:10,300

graph here so this includes some

29

00:01:15,539 --> 00:01:12,070

general-purpose telescopes like Hubble

30

00:01:18,390 --> 00:01:15,549

and Spitzer and Gaia that as well as

31

00:01:20,670 --> 00:01:18,400

dedicated missions like Koro Kepler and

32

00:01:22,410 --> 00:01:20,680

the recently launched test mission and

33

00:01:24,569 --> 00:01:22,420

there are many more as you can see on

34

00:01:25,830 --> 00:01:24,579

the arcs that are missions approved for

35

00:01:28,410 --> 00:01:25,840

building into the future so there's a

36

00:01:30,210 --> 00:01:28,420

lot happening in exoplanets but only

37

00:01:34,230 --> 00:01:30,220

right now the James Webb Space Telescope

38

00:01:37,080 --> 00:01:34,240

is among these that can do exoplanet bio

39

00:01:39,420 --> 00:01:37,090

signatures in habitability so the

40

00:01:41,760 --> 00:01:39,430

question is what is going to come after

41

00:01:43,800 --> 00:01:41,770

these all right all these arcs are

42

00:01:45,749 --> 00:01:43,810

leading to something in the question is

43

00:01:47,520 --> 00:01:45,759

what well the United States has a

44

00:01:49,740 --> 00:01:47,530

decadal survey of astronomy and

45

00:01:51,330 --> 00:01:49,750

astrophysics that will decide what the

46

00:01:53,760 --> 00:01:51,340

next mission should be across the

47

00:01:55,740 --> 00:01:53,770

discipline and for exoplanets every 10

48

00:01:59,940 --> 00:01:55,750

years they do this and that survey is

49

00:02:02,340 --> 00:01:59,950

starting up now so the anticipation of

50

00:02:05,249 --> 00:02:02,350

that NASA headquarters about four years

51
00:02:08,010 --> 00:02:05,259
ago chartered for large mission studies

52
00:02:09,779 --> 00:02:08,020
that could go and do potentially

53
00:02:11,580 --> 00:02:09,789
exoplanet astronomy these all have

54
00:02:13,180 --> 00:02:11,590
dozens of people a millions of dollars

55
00:02:15,970 --> 00:02:13,190
invested in them

56
00:02:18,400 --> 00:02:15,980
and they will provide mission concepts

57
00:02:20,680 --> 00:02:18,410
in detail to the decadal survey to

58
00:02:22,540 --> 00:02:20,690
evaluate so these are the ones that we

59
00:02:25,000 --> 00:02:22,550
want to talk about in this session today

60
00:02:27,250 --> 00:02:25,010
after leading off with the James Webb

61
00:02:29,170 --> 00:02:27,260
Space Telescope and you'll see that they

62
00:02:31,540 --> 00:02:29,180
could do some very groundbreaking work

63
00:02:33,940 --> 00:02:31,550

for astrobiology so this session is

64

00:02:36,310 --> 00:02:33,950

intended to inform you about those

65

00:02:38,440 --> 00:02:36,320

mission concepts and JWST and get you

66

00:02:40,000 --> 00:02:38,450

thinking about what should be next so

67

00:02:42,670 --> 00:02:40,010

here's the outlook for the rest of the

68

00:02:45,340 --> 00:02:42,680

session we're going to start next with

69

00:02:47,590 --> 00:02:45,350

Vicki Meadows who is our overall

70

00:02:49,060 --> 00:02:47,600

astrobiology conference chair who will

71

00:02:50,860 --> 00:02:49,070

be talking about the James Webb Space

72

00:02:52,570 --> 00:02:50,870

Telescope and what it would do for our

73

00:03:04,620 --> 00:02:52,580

understanding of exoplanet habitability

74

00:03:08,770 --> 00:03:04,630

and bio signatures Vicki Thank You Carl

75

00:03:16,900 --> 00:03:08,780

okay so that's not what I was expecting

76

00:03:20,110 --> 00:03:16,910

I get my talk up all right so while the

77

00:03:25,150 --> 00:03:20,120

talk is coming up I just oh there we go

78

00:03:26,890 --> 00:03:25,160

perfect okay so I'm gonna talk about

79

00:03:31,420 --> 00:03:26,900

prospects for habitability and biasing

80

00:03:32,830 --> 00:03:31,430

to detection with JWST this is JWST we

81

00:03:35,350 --> 00:03:32,840

have built it it's a very large

82

00:03:38,350 --> 00:03:35,360

telescope it should launch fingers

83

00:03:40,330 --> 00:03:38,360

crossed in on the 30th of March in 2020

84

00:03:42,220 --> 00:03:40,340

one has a six and a half meter mirror

85

00:03:44,890 --> 00:03:42,230

that's the biggest thing at least us

86

00:03:46,479 --> 00:03:44,900

civilians have put up there it has an

87

00:03:48,430 --> 00:03:46,489

infrared to emit infrared wavelength

88

00:03:50,740 --> 00:03:48,440

range and the reason that's important

89

00:03:51,670 --> 00:03:50,750

for us as exoplanet people is that there

90

00:03:53,080 --> 00:03:51,680

are a lot of molecules in that

91

00:03:57,130 --> 00:03:53,090

wavelength range that were potentially

92

00:03:59,020 --> 00:03:57,140

sensitive to so JWST will be able to I

93

00:04:01,509 --> 00:03:59,030

believe based on on modeling and

94

00:04:03,009 --> 00:04:01,519

anticipation and multiple groups do that

95

00:04:05,259 --> 00:04:03,019

it will be able to probe the atmosphere

96

00:04:06,729 --> 00:04:05,269

of terrestrial planets and the primary

97

00:04:09,460 --> 00:04:06,739

way it will do this is via a technique

98

00:04:11,080 --> 00:04:09,470

called transmission spectroscopy so in

99

00:04:13,150 --> 00:04:11,090

that technique the planet passes in

100

00:04:15,910 --> 00:04:13,160

front of the star and it blocks out

101
00:04:17,770 --> 00:04:15,920
light from the star and so JWST will not

102
00:04:19,150 --> 00:04:17,780
have the capability to image the planet

103
00:04:20,740 --> 00:04:19,160
around the star it will not be able to

104
00:04:22,260 --> 00:04:20,750
see a pale blue dot sitting next to a

105
00:04:24,210 --> 00:04:22,270
bright star instead

106
00:04:26,040 --> 00:04:24,220
will observe the star and see how the

107
00:04:28,830 --> 00:04:26,050
star dims as the planet passes in front

108
00:04:30,570 --> 00:04:28,840
of it the way we study the atmosphere is

109
00:04:32,700 --> 00:04:30,580
by looking not just for the dimming due

110
00:04:34,890 --> 00:04:32,710
to the solid body of the planet but for

111
00:04:37,469 --> 00:04:34,900
any additional wavelength dependent

112
00:04:39,330 --> 00:04:37,479
dimming that comes from opacity sources

113
00:04:41,189 --> 00:04:39,340

in the atmosphere so if there's no

114

00:04:42,689 --> 00:04:41,199

atmosphere you get a certain fraction of

115

00:04:44,369 --> 00:04:42,699

the light of the star blocked out just

116

00:04:46,499 --> 00:04:44,379

by the solid you know geology of the

117

00:04:48,360 --> 00:04:46,509

planet but if there's a molecule in the

118

00:04:50,580 --> 00:04:48,370

atmosphere at a wavelength that the

119

00:04:52,439 --> 00:04:50,590

molecule absorbs you will see the planet

120

00:04:54,240 --> 00:04:52,449

appear to get bigger because the

121

00:04:56,700 --> 00:04:54,250

atmosphere is now also absorbing the

122

00:04:57,990 --> 00:04:56,710

radiation coming from the star as it

123

00:05:00,240 --> 00:04:58,000

gets passed through the atmosphere

124

00:05:02,610 --> 00:05:00,250

towards the observer so essentially what

125

00:05:04,320 --> 00:05:02,620

we're doing with it with transmission

126
00:05:06,149 --> 00:05:04,330
spectroscopy is just measuring the size

127
00:05:08,010 --> 00:05:06,159
of the planet at different wavelengths

128
00:05:09,719 --> 00:05:08,020
and at some wavelengths is just the

129
00:05:11,399 --> 00:05:09,729
solid-body and at others you'll see this

130
00:05:15,390 --> 00:05:11,409
extra opacity from molecules in the

131
00:05:16,830 --> 00:05:15,400
atmosphere so I said that and it sounds

132
00:05:18,570 --> 00:05:16,840
like it's trivial but actually it's a

133
00:05:21,059 --> 00:05:18,580
very big challenge and I like to put

134
00:05:22,709 --> 00:05:21,069
this shot up of the Earth's atmosphere

135
00:05:25,020 --> 00:05:22,719
so we call this the problem of the thin

136
00:05:26,700 --> 00:05:25,030
blue line I told you we were looking for

137
00:05:29,100 --> 00:05:26,710
that extra opacity from the atmosphere

138
00:05:31,589 --> 00:05:29,110

well there it is okay you can see the

139

00:05:33,420 --> 00:05:31,599

fraction of extra opacity we're looking

140

00:05:35,550 --> 00:05:33,430

for and so we measure that extra opacity

141

00:05:39,089 --> 00:05:35,560

basically imparts per million of dimming

142

00:05:40,620 --> 00:05:39,099

of the star so because of this thin blue

143

00:05:42,930 --> 00:05:40,630

line problem we are going to favor

144

00:05:45,149 --> 00:05:42,940

studying planets that orbit M dwarf

145

00:05:46,830 --> 00:05:45,159

stars so these are smaller stars and it

146

00:05:49,350 --> 00:05:46,840

means we can block out a larger fraction

147

00:05:51,510 --> 00:05:49,360

of the star's light and therefore get a

148

00:05:53,279 --> 00:05:51,520

bigger relative signal even if we have a

149

00:05:56,459 --> 00:05:53,289

small planet with a very thin atmosphere

150

00:05:59,120 --> 00:05:56,469

and so JWST will prefer to observe M

151
00:06:04,399 --> 00:05:59,130
dwarfs which of these much smaller stars

152
00:06:06,570 --> 00:06:04,409
the star that is the the top target for

153
00:06:09,600 --> 00:06:06,580
exoplanet habitability and biasing your

154
00:06:12,360 --> 00:06:09,610
studies with Jada JWST will be the

155
00:06:14,129 --> 00:06:12,370
Trappist one system so Travis woman is a

156
00:06:16,439 --> 00:06:14,139
star that's like right at the very edge

157
00:06:18,839 --> 00:06:16,449
of stardom it's almost a Brenda Worf

158
00:06:21,120 --> 00:06:18,849
it's not much bigger than Jupiter and so

159
00:06:22,800 --> 00:06:21,130
when it has earth sized planets orbiting

160
00:06:24,420 --> 00:06:22,810
around it they're essentially blocking

161
00:06:26,129 --> 00:06:24,430
out light from something that's only the

162
00:06:28,390 --> 00:06:26,139
size of Jupiter so that gives us a lot

163
00:06:31,030 --> 00:06:28,400

more sensitivity to the atmosphere

164

00:06:33,310 --> 00:06:31,040

so not only is it just one planet

165

00:06:35,860 --> 00:06:33,320

blocking out the star but we have seven

166

00:06:37,600 --> 00:06:35,870

in this system and that's just a

167

00:06:40,270 --> 00:06:37,610

beautiful experiment we have three in

168

00:06:41,620 --> 00:06:40,280

the conservative habitable zone and

169

00:06:43,570 --> 00:06:41,630

another one sitting in the optimistic

170

00:06:45,070 --> 00:06:43,580

habitable zone and so if we can observe

171

00:06:48,100 --> 00:06:45,080

their atmospheres we can actually do

172

00:06:49,930 --> 00:06:48,110

tests observational tests for the limits

173

00:06:51,670 --> 00:06:49,940

of the habitable zone that we have some

174

00:06:54,460 --> 00:06:51,680

interior more venus like and one

175

00:06:56,320 --> 00:06:54,470

exterior as well so we try to observe

176
00:07:01,210 --> 00:06:56,330
these planets already and here's some

177
00:07:03,850 --> 00:07:01,220
spectra taken by jws are taken by HST

178
00:07:07,200 --> 00:07:03,860
and Spitzer those are the little dots on

179
00:07:10,120 --> 00:07:07,210
there that you can see and these are

180
00:07:12,159 --> 00:07:10,130
shown to not fit a model that has a

181
00:07:14,140 --> 00:07:12,169
hydrogen dominated atmosphere and so

182
00:07:15,700 --> 00:07:14,150
what we figured out already is that we

183
00:07:17,770 --> 00:07:15,710
haven't actually detected the atmosphere

184
00:07:19,930 --> 00:07:17,780
but we have been able to constrain it

185
00:07:22,480 --> 00:07:19,940
and say it's not a big puffy hydrogen

186
00:07:25,120 --> 00:07:22,490
dominated atmosphere it's more likely to

187
00:07:27,070 --> 00:07:25,130
be terrestrial and so that's a very

188
00:07:28,600 --> 00:07:27,080

important point that we have there and I

189

00:07:30,189 --> 00:07:28,610

also want to point out El Sudoku is

190

00:07:32,320 --> 00:07:30,199

going to talk about new observations

191

00:07:34,089 --> 00:07:32,330

that have been taken that actually help

192

00:07:35,469 --> 00:07:34,099

us constrain whether or not this planet

193

00:07:37,210 --> 00:07:35,479

has something more like a terrestrial

194

00:07:39,969 --> 00:07:37,220

atmosphere so I encourage you to see her

195

00:07:42,400 --> 00:07:39,979

talk so we're observing planets orbiting

196

00:07:44,140 --> 00:07:42,410

M dwarfs and that's fascinating from

197

00:07:45,760 --> 00:07:44,150

another standpoint because M dwarfs

198

00:07:48,750 --> 00:07:45,770

undergo a very different luminosity

199

00:07:52,659 --> 00:07:48,760

evolution to our star the Sun and so

200

00:07:54,670 --> 00:07:52,669

around our star our star started out dim

201
00:07:56,920 --> 00:07:54,680
and it brightened and as it did so it

202
00:07:59,140 --> 00:07:56,930
took the planet Venus and turn it into

203
00:08:00,939 --> 00:07:59,150
an uninhabitable world like what I call

204
00:08:05,050 --> 00:08:00,949
the popcorn of the solar system right so

205
00:08:07,180 --> 00:08:05,060
Venus is in that state for M dwarfs what

206
00:08:09,400 --> 00:08:07,190
happens is that the star starts out very

207
00:08:12,129 --> 00:08:09,410
very bright and then collapses down to

208
00:08:14,200 --> 00:08:12,139
its final main sequence size and then is

209
00:08:16,360 --> 00:08:14,210
dimmer and then starts to brighten very

210
00:08:18,250 --> 00:08:16,370
gradually from there so pretty much all

211
00:08:20,800 --> 00:08:18,260
of the planets that we see in the

212
00:08:22,960 --> 00:08:20,810
habitable zone of M dwarf stars have

213
00:08:24,490 --> 00:08:22,970

undergone that popcorn stage very early

214

00:08:26,710 --> 00:08:24,500

on so they've all been subjected to very

215

00:08:28,570 --> 00:08:26,720

high levels of radiation so this is

216

00:08:30,909 --> 00:08:28,580

fascinating because what we might see

217

00:08:32,560 --> 00:08:30,919

then or depressing whichever way you

218

00:08:34,300 --> 00:08:32,570

want to look at it is what we might see

219

00:08:36,339 --> 00:08:34,310

as a bunch of Venus's that even extend

220

00:08:38,440 --> 00:08:36,349

throughout the habitable zone but we may

221

00:08:40,810 --> 00:08:38,450

not see that so the first thing we're

222

00:08:41,260 --> 00:08:40,820

going to really try and do with JWST is

223

00:08:42,580 --> 00:08:41,270

for

224

00:08:44,620 --> 00:08:42,590

are we looking at worlds that went

225

00:08:46,150 --> 00:08:44,630

popcorn or I'll be looking at worlds

226

00:08:48,970 --> 00:08:46,160

that were able to retain habitability

227

00:08:50,290 --> 00:08:48,980

despite all of these processes so I'm

228

00:08:52,120 --> 00:08:50,300

just very quickly now going to go

229

00:08:55,600 --> 00:08:52,130

through you know what can we learn about

230

00:08:56,860 --> 00:08:55,610

these planets with JWST first thing do

231

00:08:58,240 --> 00:08:56,870

they have atmospheres or has it been

232

00:09:00,460 --> 00:08:58,250

stripped away by the activity of the

233

00:09:04,060 --> 00:09:00,470

star it should be pretty straightforward

234

00:09:06,820 --> 00:09:04,070

to detect atmospheres with JWST and two

235

00:09:09,340 --> 00:09:06,830

independent groups have actually shown

236

00:09:11,710 --> 00:09:09,350

that you you're looking at a handful of

237

00:09:13,690 --> 00:09:11,720

transits across the star that have to be

238

00:09:14,980 --> 00:09:13,700

Co added to be able to distinguish

239

00:09:17,200 --> 00:09:14,990

whether or not they in fact have

240

00:09:18,850 --> 00:09:17,210

terrestrial type atmospheres so that's

241

00:09:20,280 --> 00:09:18,860

fantastic so we should be able to tell

242

00:09:22,510 --> 00:09:20,290

whether they have atmospheres or not

243

00:09:25,300 --> 00:09:22,520

beyond that it gets a little bit harder

244

00:09:26,590 --> 00:09:25,310

so we might be able to comment outside

245

00:09:28,000 --> 00:09:26,600

by the way a sort of the universal

246

00:09:30,070 --> 00:09:28,010

beacon of a terrestrial planet

247

00:09:31,690 --> 00:09:30,080

atmosphere it shows up at a whole range

248

00:09:33,580 --> 00:09:31,700

of abundances even you know at

249

00:09:35,920 --> 00:09:33,590

earth-like abundances in the atmosphere

250

00:09:37,750 --> 00:09:35,930

so we'll go after carbon dioxide which

251
00:09:39,820 --> 00:09:37,760
has a very very strong features you can

252
00:09:43,300 --> 00:09:39,830
see there in the spectra we'll go after

253
00:09:45,580 --> 00:09:43,310
water vapor although that could be very

254
00:09:47,050 --> 00:09:45,590
challenging to observe especially with

255
00:09:49,180 --> 00:09:47,060
the cloud decks that come with water

256
00:09:51,040 --> 00:09:49,190
vapor and also with the the troposphere

257
00:09:52,750 --> 00:09:51,050
a cold trap that we like to have to keep

258
00:09:54,010 --> 00:09:52,760
the water down there so for a habitable

259
00:09:56,940 --> 00:09:54,020
planet it's going to be relatively

260
00:10:00,130 --> 00:09:56,950
difficult to observe water vapor in fact

261
00:10:01,510 --> 00:10:00,140
but you know maybe after 125 transits

262
00:10:03,670 --> 00:10:01,520
and the bad news is that for traffice

263
00:10:05,770 --> 00:10:03,680

won't eat is only 81 transits available

264

00:10:08,290 --> 00:10:05,780

in the entire five-year nominal mission

265

00:10:11,770 --> 00:10:08,300

of JWST so water it might actually be

266

00:10:14,170 --> 00:10:11,780

quite hard however we may be able to

267

00:10:16,360 --> 00:10:14,180

tell if the planet lost an ocean easier

268

00:10:18,670 --> 00:10:16,370

than telling if the planet has one now

269

00:10:19,900 --> 00:10:18,680

so we may be able to tell the planet is

270

00:10:22,210 --> 00:10:19,910

dead better than can tell it is

271

00:10:24,150 --> 00:10:22,220

habitable so the signs of the ocean that

272

00:10:26,620 --> 00:10:24,160

we could look for are things called

273

00:10:28,660 --> 00:10:26,630

collision induced absorption from oxygen

274

00:10:30,460 --> 00:10:28,670

so oxygen molecules batting against each

275

00:10:31,900 --> 00:10:30,470

other when you lose an ocean you build

276

00:10:33,940 --> 00:10:31,910

up huge amounts of oxygen in the

277

00:10:35,410 --> 00:10:33,950

atmosphere because the water vapor goes

278

00:10:37,420 --> 00:10:35,420

up it gets fertilized the hydrogen

279

00:10:39,550 --> 00:10:37,430

escapes whether or not the planet

280

00:10:40,840 --> 00:10:39,560

retains that oxygen atmosphere over

281

00:10:42,610 --> 00:10:40,850

billions of years is an interesting

282

00:10:44,530 --> 00:10:42,620

experiment we can now test observational

283

00:10:45,640 --> 00:10:44,540

ii so we will look for massive amounts

284

00:10:47,110 --> 00:10:45,650

of oxygen that are not due to a

285

00:10:49,720 --> 00:10:47,120

biosphere that might be due to a lost

286

00:10:51,880 --> 00:10:49,730

ocean we could also potentially look for

287

00:10:53,660 --> 00:10:51,890

fractionation things like hto the sort

288

00:10:54,950 --> 00:10:53,670

of signal that we see from Venus

289

00:10:56,570 --> 00:10:54,960

and it turns out that that in

290

00:10:58,730 --> 00:10:56,580

transmission might not be as difficult

291

00:11:00,050 --> 00:10:58,740

to detect as we expect missus work done

292

00:11:02,480 --> 00:11:00,060

by Angeline Kowski and you can see

293

00:11:04,550 --> 00:11:02,490

Andrews talk after the break as well but

294

00:11:07,130 --> 00:11:04,560

we may need only 10 to 12 transits to

295

00:11:08,660 --> 00:11:07,140

actually detect HDO if it's it at the

296

00:11:13,070 --> 00:11:08,670

sort of fractionation enhancement that

297

00:11:14,960 --> 00:11:13,080

Venus has so detecting earth-like oxygen

298

00:11:17,180 --> 00:11:14,970

now moving to biosignatures is unlikely

299

00:11:18,560 --> 00:11:17,190

with JWST and i am very depressed about

300

00:11:20,390 --> 00:11:18,570

that i thought we might be able to do

301
00:11:23,420 --> 00:11:20,400
the 1.2 7 micron band which is much

302
00:11:25,430 --> 00:11:23,430
stronger than the classic 0.76 but

303
00:11:28,010 --> 00:11:25,440
essentially they're pretty much hopeless

304
00:11:30,290 --> 00:11:28,020
so we get signal-to-noise of 1 in 30

305
00:11:31,430 --> 00:11:30,300
transits so 270 transits and I've

306
00:11:34,450 --> 00:11:31,440
already told you that's only 81

307
00:11:38,420 --> 00:11:34,460
available for signal-to-noise or 3 so

308
00:11:39,800 --> 00:11:38,430
you can get other other groups have also

309
00:11:42,770 --> 00:11:39,810
looked at this with a more sort of

310
00:11:46,160 --> 00:11:42,780
optimistic model and they still get 172

311
00:11:49,250 --> 00:11:46,170
so I haven't got high hopes for oxygen

312
00:11:51,140 --> 00:11:49,260
however JWST will be very sensitive to

313
00:11:52,730 --> 00:11:51,150

biogenic levels of methane coming from

314

00:11:54,590 --> 00:11:52,740

the planet because methane builds up in

315

00:11:56,180 --> 00:11:54,600

the atmosphere of M dome of planets due

316

00:11:58,040 --> 00:11:56,190

to the spectrum of the star which

317

00:12:01,250 --> 00:11:58,050

doesn't destroy methane as effectively

318

00:12:02,900 --> 00:12:01,260

in its reactions so we might be able to

319

00:12:04,550 --> 00:12:02,910

do you know methane a very strong

320

00:12:06,500 --> 00:12:04,560

methane pretty easily in about 50

321

00:12:08,240 --> 00:12:06,510

transits still a huge fraction of the

322

00:12:09,200 --> 00:12:08,250

amount available but hey we'll be

323

00:12:12,950 --> 00:12:09,210

detecting something that's potentially

324

00:12:15,140 --> 00:12:12,960

biogenic so we may also the bio

325

00:12:16,610 --> 00:12:15,150

signatures we might see our co2 and

326

00:12:18,110 --> 00:12:16,620

methane disequilibrium and something

327

00:12:19,940 --> 00:12:18,120

this is something that judge Kristensen

328

00:12:22,730 --> 00:12:19,950

totten has pointed out if you have

329

00:12:24,290 --> 00:12:22,740

biogenic methane fluxes it tends to

330

00:12:26,660 --> 00:12:24,300

produce a much larger amount of methane

331

00:12:28,820 --> 00:12:26,670

in the atmosphere so we may be able to

332

00:12:30,200 --> 00:12:28,830

detect that and Giada has worked on and

333

00:12:32,330 --> 00:12:30,210

showing that that could also form a haze

334

00:12:35,030 --> 00:12:32,340

which would also be sort of a bio

335

00:12:36,290 --> 00:12:35,040

signature of measure as well detecting

336

00:12:38,090 --> 00:12:36,300

much more complex biosignatures

337

00:12:39,920 --> 00:12:38,100

molecules though is hard we've looked at

338

00:12:41,540 --> 00:12:39,930

work that Shawn did looking at sulfur

339

00:12:43,670 --> 00:12:41,550

biospheres looking for things like

340

00:12:45,470 --> 00:12:43,680

ethane and dimethyl sulfide they do

341

00:12:47,360 --> 00:12:45,480

produce features in the spectrum but you

342

00:12:50,000 --> 00:12:47,370

can see there from the error bars that

343

00:12:51,410 --> 00:12:50,010

in the the the range of the longer

344

00:12:54,320 --> 00:12:51,420

wavelength instrument we really aren't

345

00:12:55,820 --> 00:12:54,330

sensitive to these but I also point out

346

00:12:57,620 --> 00:12:55,830

there that ironically if the planet has

347

00:12:59,360 --> 00:12:57,630

a haze we actually get a bigger signal

348

00:13:01,400 --> 00:12:59,370

because the haze photochemically

349

00:13:02,730 --> 00:13:01,410

protects those more complex molecules

350

00:13:04,740 --> 00:13:02,740

from being destroyed

351

00:13:06,720 --> 00:13:04,750

so in summary for biasing interest we

352

00:13:07,800 --> 00:13:06,730

won't get oxygen we might get co2 and

353

00:13:09,750 --> 00:13:07,810

methane we might be able to pull a

354

00:13:11,960 --> 00:13:09,760

disequilibrium out of a sort of early

355

00:13:13,830 --> 00:13:11,970

earth type atmosphere we may get haze

356

00:13:15,990 --> 00:13:13,840

but we're not gonna get probably the

357

00:13:17,610 --> 00:13:16,000

more complicated things so I'll leave my

358

00:13:19,380 --> 00:13:17,620

summary out there of what we will get

359

00:13:20,790 --> 00:13:19,390

so we'll get first detection of

360

00:13:23,070 --> 00:13:20,800

terrestrial atmospheres first detection

361

00:13:25,080 --> 00:13:23,080

of gases possible confirmation of past

362

00:13:27,780 --> 00:13:25,090

or current ocean loss maybe a co2

363

00:13:30,360 --> 00:13:27,790

methane biosignature but we will not get

364

00:13:32,460 --> 00:13:30,370

definitive indication of current

365

00:13:34,500 --> 00:13:32,470

habitability or if like oxygen 'ok

366

00:13:35,820 --> 00:13:34,510

further synthesis and so for that i'm

367

00:13:46,560 --> 00:13:35,830

looking forward to the future main

368

00:13:48,660 --> 00:13:46,570

missions that will come Thank You Vicki

369

00:13:49,950 --> 00:13:48,670

next up we'll have Kevin Stevenson from

370

00:13:51,630 --> 00:13:49,960

the Space Telescope Science Institute

371

00:13:53,940 --> 00:13:51,640

who will be telling us about all the

372

00:13:58,400 --> 00:13:53,950

wonderful things the origins mission

373

00:14:00,360 --> 00:13:58,410

concept can do for exoplanets Kevin

374

00:14:02,550 --> 00:14:00,370

alright before I get started I'd like to

375

00:14:04,980 --> 00:14:02,560

thank Tiffany kantaria and Jonathan

376

00:14:06,660 --> 00:14:04,990

Fortney who are co-leads of the

377

00:14:13,170 --> 00:14:06,670

exoplanet science working group and also

378

00:14:15,660 --> 00:14:13,180

the members of the working group here ok

379

00:14:17,310 --> 00:14:15,670

so the origin space telescope is from

380

00:14:19,130 --> 00:14:17,320

the community by the community and for

381

00:14:21,540 --> 00:14:19,140

the community and what I mean by that is

382

00:14:23,340 --> 00:14:21,550

originally the original space telescope

383

00:14:25,470 --> 00:14:23,350

was a far infrared surveyor mission

384

00:14:27,360 --> 00:14:25,480

concept and it was really designed the

385

00:14:30,390 --> 00:14:27,370

process of the astrophysics roadmap back

386

00:14:32,130 --> 00:14:30,400

in 2013 and it has involved forward into

387

00:14:33,930 --> 00:14:32,140

this origin Space Telescope mission

388

00:14:35,400 --> 00:14:33,940

concept where we're focusing not only on

389

00:14:37,080 --> 00:14:35,410

the foreign threat but also in the mid

390

00:14:39,480 --> 00:14:37,090

infrared and is brought to you by

391

00:14:41,550 --> 00:14:39,490

community members so members of the

392

00:14:43,500 --> 00:14:41,560

astrophysics community and astrobiology

393

00:14:45,090 --> 00:14:43,510

community have been involved in the

394

00:14:47,160 --> 00:14:45,100

science technology definition team

395

00:14:48,960 --> 00:14:47,170

planning out these observations and

396

00:14:50,940 --> 00:14:48,970

designing the mission concept and really

397

00:14:53,520 --> 00:14:50,950

it will be for the community before

398

00:14:55,080 --> 00:14:53,530

everyone who can propose for telescope

399

00:14:56,400 --> 00:14:55,090

time about half of the telescope time

400

00:14:58,410 --> 00:14:56,410

available will be open to the community

401
00:15:01,140 --> 00:14:58,420
so they can perform their own guest

402
00:15:03,270 --> 00:15:01,150
observer observations now there are

403
00:15:04,830 --> 00:15:03,280
three high-level scientific questions

404
00:15:06,510 --> 00:15:04,840
that the astrophysics division is

405
00:15:07,980 --> 00:15:06,520
interested in answering and those

406
00:15:09,780 --> 00:15:07,990
questions are how did you do how does

407
00:15:12,240 --> 00:15:09,790
the universe work how did we get here

408
00:15:13,830 --> 00:15:12,250
and are we alone in the universe and so

409
00:15:15,390 --> 00:15:13,840
the origin space telescope is looking to

410
00:15:15,630 --> 00:15:15,400
address those three questions but I'm

411
00:15:17,340 --> 00:15:15,640
going to

412
00:15:19,830 --> 00:15:17,350
focus on the third one here and I'm

413
00:15:22,740 --> 00:15:19,840

gonna reframe that into a question about

414

00:15:25,020 --> 00:15:22,750

M Dwarfs do planets orbiting M dwarf

415

00:15:26,100 --> 00:15:25,030

stars support life that is a question

416

00:15:28,530 --> 00:15:26,110

that we're looking to answer with

417

00:15:29,820 --> 00:15:28,540

origins before we get into that let me

418

00:15:31,740 --> 00:15:29,830

talk a little bit about these M dwarf

419

00:15:33,450 --> 00:15:31,750

stars Vicki gave a great introduction to

420

00:15:36,180 --> 00:15:33,460

the Trappist one system and I'm showing

421

00:15:38,460 --> 00:15:36,190

you here the Sun and Travis one on scale

422

00:15:40,710 --> 00:15:38,470

is roughly the size of Jupiter as Vicki

423

00:15:43,200 --> 00:15:40,720

mentioned so M dwarfs are very common

424

00:15:45,240 --> 00:15:43,210

within the galaxy about 75% of stars

425

00:15:46,740 --> 00:15:45,250

within fifteen parsecs which are those

426

00:15:48,570 --> 00:15:46,750

that we want to actually look at in

427

00:15:52,440 --> 00:15:48,580

terms of characterizing planets in their

428

00:15:54,570 --> 00:15:52,450

the atmospheres of planets and so and a

429

00:15:56,160 --> 00:15:54,580

lot of these and planets around M dwarfs

430

00:15:57,750 --> 00:15:56,170

are rocky as we've seen with the

431

00:15:59,760 --> 00:15:57,760

Trappist one system where we have seven

432

00:16:02,010 --> 00:15:59,770

planets of which three possibly four are

433

00:16:04,830 --> 00:16:02,020

in the habitable zone so we have a huge

434

00:16:06,750 --> 00:16:04,840

advantage of these transiting small

435

00:16:08,340 --> 00:16:06,760

rocky planets around these M Dwarfs

436

00:16:10,860 --> 00:16:08,350

they're close into the habit of zone

437

00:16:12,900 --> 00:16:10,870

have a high transit probability and also

438

00:16:14,070 --> 00:16:12,910

larger transit depths now this is

439

00:16:15,480 --> 00:16:14,080

actually very important when you're

440

00:16:16,920 --> 00:16:15,490

talking about the signal sizes that

441

00:16:18,930 --> 00:16:16,930

you're looking for now in case you

442

00:16:21,360 --> 00:16:18,940

missed it with Vicky's talk just

443

00:16:23,040 --> 00:16:21,370

beforehand the transit technique is when

444

00:16:24,900 --> 00:16:23,050

the planet crosses in front of the star

445

00:16:26,250 --> 00:16:24,910

and blocks out some of that light and

446

00:16:28,500 --> 00:16:26,260

what we're interested in is that little

447

00:16:31,260 --> 00:16:28,510

sliver of light around sort of an

448

00:16:33,630 --> 00:16:31,270

annulus of the planet and so the transit

449

00:16:35,970 --> 00:16:33,640

signal goes over 1 over the radius of

450

00:16:38,250 --> 00:16:35,980

the star squared so by decreasing the

451
00:16:40,170 --> 00:16:38,260
size of the star we really improve and

452
00:16:43,440 --> 00:16:40,180
increase the size of the signal that

453
00:16:46,950 --> 00:16:43,450
we're looking for so as of a couple of

454
00:16:49,620 --> 00:16:46,960
weeks ago June 2019 there are over 4,000

455
00:16:51,360 --> 00:16:49,630
confirmed exoplanets 3/4 of which have

456
00:16:53,790 --> 00:16:51,370
been discovered using the transit

457
00:16:55,560 --> 00:16:53,800
technique now a full one-third of those

458
00:16:57,180 --> 00:16:55,570
that's a thousand planets are

459
00:16:59,550 --> 00:16:57,190
terrestrial in nature and by that I mean

460
00:17:03,030 --> 00:16:59,560
they have rocky surfaces most likely

461
00:17:06,180 --> 00:17:03,040
with a thin or slightly can opaque

462
00:17:07,650 --> 00:17:06,190
atmosphere now moving forward beyond

463
00:17:08,939 --> 00:17:07,660

that we have the test mission which is

464

00:17:10,860 --> 00:17:08,949

currently looking for transiting

465

00:17:13,800 --> 00:17:10,870

exoplanets and already they found almost

466

00:17:17,490 --> 00:17:13,810

800 exoplanet candidates many of which

467

00:17:18,720 --> 00:17:17,500

will go on to be confirmed okay so what

468

00:17:20,579 --> 00:17:18,730

are the advantages of the transit

469

00:17:22,350 --> 00:17:20,589

technique first of all we have a mass

470

00:17:24,120 --> 00:17:22,360

and a radius those are two fundamental

471

00:17:25,540 --> 00:17:24,130

properties that we gain from measuring

472

00:17:27,220 --> 00:17:25,550

the size of the planet

473

00:17:29,200 --> 00:17:27,230

the masses with the radial velocity or

474

00:17:31,360 --> 00:17:29,210

transit timing variations and what that

475

00:17:33,610 --> 00:17:31,370

gives us is a bulk density here that

476
00:17:35,950 --> 00:17:33,620
that allows us to understand or put the

477
00:17:37,540 --> 00:17:35,960
the planet into context and to assess

478
00:17:40,330 --> 00:17:37,550
whether or not the planet actually has

479
00:17:43,300 --> 00:17:40,340
an atmosphere is predominantly rocky or

480
00:17:45,160 --> 00:17:43,310
perhaps is a big ball of gas so here I'm

481
00:17:48,160 --> 00:17:45,170
showing you mass radius diagram of the

482
00:17:50,110 --> 00:17:48,170
Trappist one system and these constant

483
00:17:52,570 --> 00:17:50,120
density curves you can see I also have

484
00:17:54,700 --> 00:17:52,580
Earth and Venus for reference and so

485
00:17:56,680 --> 00:17:54,710
many of the planets in the Trappist 1

486
00:17:58,780 --> 00:17:56,690
system are above that grey line which

487
00:18:00,550 --> 00:17:58,790
suggests that they're volatile rich so

488
00:18:02,140 --> 00:18:00,560

it's likely these planets have a

489

00:18:04,750 --> 00:18:02,150

significant amount of water in their

490

00:18:06,700 --> 00:18:04,760

atmospheres now this is a very good sign

491

00:18:08,440 --> 00:18:06,710

if this holds true with more precise

492

00:18:10,000 --> 00:18:08,450

measurements because then that suggests

493

00:18:14,560 --> 00:18:10,010

that these systems are not in that sort

494

00:18:16,120 --> 00:18:14,570

of popcorn state all right so the

495

00:18:18,280 --> 00:18:16,130

mid-infrared is one of the key

496

00:18:19,420 --> 00:18:18,290

wavelength ranges that were interested

497

00:18:21,040 --> 00:18:19,430

particularly for the search of

498

00:18:22,660 --> 00:18:21,050

biosignatures now if you want to

499

00:18:25,060 --> 00:18:22,670

actually measure photons being emitted

500

00:18:28,930 --> 00:18:25,070

from a planet you have to go into the

501

00:18:31,330 --> 00:18:28,940

infrared stars like our Sun it emit in

502

00:18:33,160 --> 00:18:31,340

the optical but AC go down to cooler and

503

00:18:35,890 --> 00:18:33,170

cooler planets this spectral radiance

504

00:18:37,690 --> 00:18:35,900

curve here indicates that at 250 Kelvin

505

00:18:39,910 --> 00:18:37,700

you really want to be focusing on that 7

506

00:18:42,010 --> 00:18:39,920

to 15 micron range that's where the the

507

00:18:44,410 --> 00:18:42,020

sort of the sweet spot is for measuring

508

00:18:48,700 --> 00:18:44,420

photons with respect to whatever the

509

00:18:51,070 --> 00:18:48,710

whatever star you're orbiting so here we

510

00:18:52,900 --> 00:18:51,080

have this instead of a blackbody curve

511

00:18:54,700 --> 00:18:52,910

this is an actual stimulated emission

512

00:18:57,280 --> 00:18:54,710

spectrum of the earth and you can see

513

00:18:59,200 --> 00:18:57,290

that it Peaks around 10 microns and all

514

00:19:01,330 --> 00:18:59,210

of the features that I'm showing here we

515

00:19:03,550 --> 00:19:01,340

have habitability indicators for example

516

00:19:05,350 --> 00:19:03,560

like carbon dioxide and water and also

517

00:19:07,630 --> 00:19:05,360

bio signature pairs for example like

518

00:19:09,790 --> 00:19:07,640

ozone and nitrous oxide our zone and

519

00:19:11,800 --> 00:19:09,800

methane and all of them are in the mid

520

00:19:13,440 --> 00:19:11,810

infrared wavelengths so if we if we

521

00:19:15,640 --> 00:19:13,450

really want to be searching for

522

00:19:18,820 --> 00:19:15,650

biosignatures this is the optimum

523

00:19:20,290 --> 00:19:18,830

wavelength range to search for so going

524

00:19:22,000 --> 00:19:20,300

back to this question do planets

525

00:19:25,680 --> 00:19:22,010

orbiting m dwarf star support life

526
00:19:29,050 --> 00:19:25,690
really what we wanted understand is is

527
00:19:30,790 --> 00:19:29,060
building up a a signal to noise that we

528
00:19:32,950 --> 00:19:30,800
can actually make a definitive

529
00:19:34,750 --> 00:19:32,960
measurement for these molecules and as

530
00:19:36,850 --> 00:19:34,760
Vicki pointed out we need a large number

531
00:19:39,039 --> 00:19:36,860
of transits to do that in

532
00:19:41,470 --> 00:19:39,049
many cases we'll need at least 40

533
00:19:43,480 --> 00:19:41,480
transit observations if not more to

534
00:19:45,460 --> 00:19:43,490
improve the signal to such a point we

535
00:19:47,380 --> 00:19:45,470
can make a definitive detection so I'm

536
00:19:48,610 --> 00:19:47,390
showing you the relative transit depth

537
00:19:50,950 --> 00:19:48,620
this is when the planet goes in front of

538
00:19:53,110 --> 00:19:50,960

the star as a function of wavelength and

539

00:19:54,490 --> 00:19:53,120

the signal-to-noise improves as we

540

00:19:55,840 --> 00:19:54,500

increase the number of transits so here

541

00:19:57,850 --> 00:19:55,850

I'm just showing you a case of 40

542

00:19:59,410 --> 00:19:57,860

transits and depending on the brightness

543

00:20:01,810 --> 00:19:59,420

of star we make me may need

544

00:20:05,380 --> 00:20:01,820

significantly more and also depending on

545

00:20:08,140 --> 00:20:05,390

the molecule so this is where the origin

546

00:20:10,120 --> 00:20:08,150

space telescope was designed with the

547

00:20:12,190 --> 00:20:10,130

James Webb Space Telescope there are

548

00:20:14,049 --> 00:20:12,200

only probably going to be about 80 to 85

549

00:20:15,640 --> 00:20:14,059

transit observations available of the

550

00:20:17,710 --> 00:20:15,650

Trappist 1e system over its lifetime

551
00:20:19,419 --> 00:20:17,720
with origins it's being designed with

552
00:20:21,880 --> 00:20:19,429
larger field of regard this will allow

553
00:20:24,940 --> 00:20:21,890
you to obtain more transits that were

554
00:20:26,549 --> 00:20:24,950
given in the year and therefore build up

555
00:20:28,450 --> 00:20:26,559
to higher signals noise

556
00:20:30,310 --> 00:20:28,460
additionally origins will have

557
00:20:32,860 --> 00:20:30,320
simultaneous wavelength coverage this

558
00:20:34,870 --> 00:20:32,870
will go from 3 to 20 microns and enable

559
00:20:36,400 --> 00:20:34,880
you to measure key spectroscopic

560
00:20:38,740 --> 00:20:36,410
signatures like the ones that I've

561
00:20:40,240 --> 00:20:38,750
discussing prior and also it will have

562
00:20:42,159 --> 00:20:40,250
an instrument designed specifically for

563
00:20:45,039 --> 00:20:42,169

high-precision time series observations

564

00:20:47,260 --> 00:20:45,049

this means higher throughput with the

565

00:20:49,570 --> 00:20:47,270

detector and lower noise floor which is

566

00:20:51,280 --> 00:20:49,580

actually a key question as to how well

567

00:20:53,200 --> 00:20:51,290

the instruments on James Webb will

568

00:20:55,330 --> 00:20:53,210

perform and really we won't be able to

569

00:20:57,070 --> 00:20:55,340

answer that question until we move

570

00:20:59,500 --> 00:20:57,080

forward and do the observations in a

571

00:21:02,409 --> 00:20:59,510

couple of years so here I'm showing you

572

00:21:04,299 --> 00:21:02,419

comparison between James Webb on the top

573

00:21:06,100 --> 00:21:04,309

and Origin Space Telescope on the bottom

574

00:21:08,289 --> 00:21:06,110

and one of the key things you'll notice

575

00:21:09,789 --> 00:21:08,299

is that James Webb given the the

576

00:21:11,650 --> 00:21:09,799

instrument design in the layout it

577

00:21:13,539 --> 00:21:11,660

requires essentially twice as many

578

00:21:16,030 --> 00:21:13,549

transit observations to have similar

579

00:21:17,980 --> 00:21:16,040

wavelength coverage so that really makes

580

00:21:21,700 --> 00:21:17,990

it a challenging prospect to look for

581

00:21:25,600 --> 00:21:21,710

biosignatures with JWST in non-ideal eye

582

00:21:27,789 --> 00:21:25,610

setting and when we look at the

583

00:21:29,560 --> 00:21:27,799

comparison between origins James Webb if

584

00:21:30,850 --> 00:21:29,570

you want to do an atmospheric retrievals

585

00:21:32,700 --> 00:21:30,860

where we pull off the information that

586

00:21:35,289 --> 00:21:32,710

we can obtain from these observations

587

00:21:36,940 --> 00:21:35,299

really what we can say about James Webb

588

00:21:38,590 --> 00:21:36,950

and origins is that both of them will be

589

00:21:40,480 --> 00:21:38,600

detect will be able to detect carbon

590

00:21:41,710 --> 00:21:40,490

dioxide and this will be a primary

591

00:21:44,440 --> 00:21:41,720

indicator of whether or not these

592

00:21:45,820 --> 00:21:44,450

planets have atmospheres moving forward

593

00:21:47,830 --> 00:21:45,830

looking at the bio signature

594

00:21:50,020 --> 00:21:47,840

combinations for example nitrous oxide

595

00:21:50,360 --> 00:21:50,030

and ozone what we can see is that under

596

00:21:52,250 --> 00:21:50,370

these

597

00:21:54,320 --> 00:21:52,260

options of the given noise floors 20 and

598

00:21:56,270 --> 00:21:54,330

30 ppm for the near spec and Miri

599

00:21:58,280 --> 00:21:56,280

instruments James Webb will have a

600

00:22:00,350 --> 00:21:58,290

difficult time it'll be challenging to

601
00:22:02,030 --> 00:22:00,360
detect those bio signatures if the

602
00:22:04,910 --> 00:22:02,040
instruments perform better than they

603
00:22:07,880 --> 00:22:04,920
were zoomed values we may actually have

604
00:22:09,980 --> 00:22:07,890
a significant detection here with Origin

605
00:22:11,990 --> 00:22:09,990
Space Telescope we have a 5 ppm noise

606
00:22:13,790 --> 00:22:12,000
floor and as you can see we can detect

607
00:22:18,440 --> 00:22:13,800
this path signature pair at greater than

608
00:22:20,210 --> 00:22:18,450
3.6 segment confidence okay so to

609
00:22:22,130 --> 00:22:20,220
summarize my talk I want to emphasize

610
00:22:24,049 --> 00:22:22,140
that the M dwarfs are very important

611
00:22:25,700 --> 00:22:24,059
targets in the search for life and they

612
00:22:27,799 --> 00:22:25,710
will be the ones in which James Webb

613
00:22:29,120 --> 00:22:27,809

will start that process and afterwards

614

00:22:31,090 --> 00:22:29,130

hopefully origins will be able to

615

00:22:33,440 --> 00:22:31,100

continue on looking for bio signatures

616

00:22:35,330 --> 00:22:33,450

origins itself will characterize the

617

00:22:37,850 --> 00:22:35,340

atmospheres of planets that have been

618

00:22:39,260 --> 00:22:37,860

previously detected through the transit

619

00:22:40,700 --> 00:22:39,270

and radial velocity techniques which

620

00:22:43,130 --> 00:22:40,710

means they will have known masses and

621

00:22:45,860 --> 00:22:43,140

radii are a radii prior to atmospheric

622

00:22:48,230 --> 00:22:45,870

characterization and origins we'll be

623

00:22:50,060 --> 00:22:48,240

looking at in the mid infrared where all

624

00:22:52,070 --> 00:22:50,070

of these features the bio signatures and

625

00:22:54,710 --> 00:22:52,080

habitability indicators have spectral

626
00:22:56,900 --> 00:22:54,720
features so using the transmission and

627
00:22:58,730 --> 00:22:56,910
mission spectroscopy techniques origins

628
00:23:00,940 --> 00:22:58,740
will assess the habitability of nearby

629
00:23:10,280 --> 00:23:00,950
EXO piouss and search for signs of life

630
00:23:15,360 --> 00:23:13,110
thank you Kevin our next speaker if we

631
00:23:17,070 --> 00:23:15,370
get the slides up will be dr. Giada

632
00:23:18,930 --> 00:23:17,080
Arnie who is my colleague at NASA's

633
00:23:20,600 --> 00:23:18,940
Goddard Space Flight Center and is also

634
00:23:26,280 --> 00:23:20,610
the lead of the leVoir teams

635
00:23:27,480 --> 00:23:26,290
science support and analysis team wait a

636
00:23:33,470 --> 00:23:27,490
second while we get those slides up

637
00:23:38,220 --> 00:23:36,600
alright so hello everybody I'm Joe Arnie

638
00:23:40,050 --> 00:23:38,230

I am a planetary scientist and

639

00:23:41,820 --> 00:23:40,060

astrobiologists and NASA Goddard I'm

640

00:23:43,470 --> 00:23:41,830

really delighted to be here talking

641

00:23:45,120 --> 00:23:43,480

about the Louvre our mission concept

642

00:23:46,800 --> 00:23:45,130

which I'm really excited about I'm

643

00:23:48,750 --> 00:23:46,810

especially excited about it to be

644

00:23:51,870 --> 00:23:48,760

talking about it at apps icon which is

645

00:23:54,720 --> 00:23:51,880

easily my favorite conference so what

646

00:23:57,210 --> 00:23:54,730

exactly is Louvre our leVoir is a large

647

00:23:59,070 --> 00:23:57,220

Space Telescope concept in the tradition

648

00:24:00,540 --> 00:23:59,080

of Hubble so it stands for the large

649

00:24:04,080 --> 00:24:00,550

ultraviolet optical Infrared Survey

650

00:24:05,400 --> 00:24:04,090

telescope that L enlarge is not a lie

651
00:24:08,240 --> 00:24:05,410
and I'll show you on the next slide how

652
00:24:10,650 --> 00:24:08,250
big blue bar is we think of it as

653
00:24:12,660 --> 00:24:10,660
similar to Hubble in that has a similar

654
00:24:15,600 --> 00:24:12,670
wavelength range to Hubble from the far

655
00:24:17,850 --> 00:24:15,610
UV to the near IR I mean we have a suite

656
00:24:20,160 --> 00:24:17,860
of imagers and spectrographs on board

657
00:24:22,200 --> 00:24:20,170
that are versatile and capable enough of

658
00:24:24,090 --> 00:24:22,210
answering questions that we can't yet

659
00:24:26,130 --> 00:24:24,100
conceive of similar to what Hubble did

660
00:24:27,720 --> 00:24:26,140
on this Observatory would be serviceable

661
00:24:29,700 --> 00:24:27,730
and upgradable and would have a time

662
00:24:31,350 --> 00:24:29,710
allocation model following what Hubble

663
00:24:34,350 --> 00:24:31,360

does and that this would be a primarily

664

00:24:37,410 --> 00:24:34,360

guest observer driven facility ok so how

665

00:24:39,660 --> 00:24:37,420

big is Lavar a salut bar a is the big

666

00:24:41,640 --> 00:24:39,670

sister version of the two architectures

667

00:24:44,970 --> 00:24:41,650

that we're currently studying levare is

668

00:24:48,240 --> 00:24:44,980

a 15 meter telescope to put that into

669

00:24:49,590 --> 00:24:48,250

perspective Hubble has a diameter of 2.4

670

00:24:51,480 --> 00:24:49,600

meters and the James Webb Space

671

00:24:54,240 --> 00:24:51,490

Telescope has a diameter of 6 and 1/2

672

00:24:55,380 --> 00:24:54,250

meters right so this is a big light

673

00:24:59,010 --> 00:24:55,390

collecting bucket

674

00:25:00,900 --> 00:24:59,020

Lavar be the little sister to levare but

675

00:25:04,440 --> 00:25:00,910

she's still pretty big is an 8 meter

676

00:25:05,940 --> 00:25:04,450

telescope right so still too large still

677

00:25:10,080 --> 00:25:05,950

larger than James Webb not quite as

678

00:25:11,970 --> 00:25:10,090

large as leVaire the reason why leVair

679

00:25:13,770 --> 00:25:11,980

has been driven to such large apertures

680

00:25:15,510 --> 00:25:13,780

is we want to maximize our chances of

681

00:25:18,110 --> 00:25:15,520

discovering life and habitable

682

00:25:20,269 --> 00:25:18,120

conditions elsewhere in our universe

683

00:25:22,970 --> 00:25:20,279

we want to see other Earth's right like

684

00:25:24,919 --> 00:25:22,980

this is the holy grail for exoplanet

685

00:25:26,299 --> 00:25:24,929

astronomers and the many astrobiologists

686

00:25:28,279 --> 00:25:26,309

we want to know if there's other

687

00:25:30,980 --> 00:25:28,289

earth-like planets out there and we're

688

00:25:34,940 --> 00:25:30,990

beginning to get a sense from exoplanet

689

00:25:36,890 --> 00:25:34,950

census surveys of how frequently rocky

690

00:25:39,080 --> 00:25:36,900

planets occur in their star's habitable

691

00:25:41,090 --> 00:25:39,090

zones and that's great and that's really

692

00:25:44,330 --> 00:25:41,100

important information but that doesn't

693

00:25:47,690 --> 00:25:44,340

actually tell us how common these things

694

00:25:50,269 --> 00:25:47,700

are right we don't know how common are

695

00:25:52,580 --> 00:25:50,279

truly habitable planets we don't yet

696

00:25:54,139 --> 00:25:52,590

know how common inhabited planets are

697

00:25:55,760 --> 00:25:54,149

and these are the questions that we

698

00:25:58,880 --> 00:25:55,770

asked our biologists really want to know

699

00:26:01,940 --> 00:25:58,890

the answers to so I'm here are the

700

00:26:04,010 --> 00:26:01,950

exoplanet excellor 'the candidate yields

701
00:26:05,840 --> 00:26:04,020
for the louvre art concepts on these are

702
00:26:08,180 --> 00:26:05,850
calculated by chris stark from the Space

703
00:26:10,610 --> 00:26:08,190
Telescope Science Institute he also

704
00:26:11,810 --> 00:26:10,620
calculated exoplanet yield to have ex

705
00:26:15,560 --> 00:26:11,820
mission concept that you'll hear from

706
00:26:18,340 --> 00:26:15,570
next so what's these large sample sizes

707
00:26:21,380 --> 00:26:18,350
allow us to do is they allow us to

708
00:26:23,659 --> 00:26:21,390
search for rare processes right we don't

709
00:26:26,029 --> 00:26:23,669
know how common habitability is we don't

710
00:26:28,549 --> 00:26:26,039
know how common life is but by observing

711
00:26:29,960 --> 00:26:28,559
a large number of planets we can you

712
00:26:32,210 --> 00:26:29,970
know minimize our chances of getting

713
00:26:34,220 --> 00:26:32,220

unlucky so this is basically insurance

714

00:26:38,180 --> 00:26:34,230

against the universe conspiring against

715

00:26:40,460 --> 00:26:38,190

us and having life be very rare so with

716

00:26:43,880 --> 00:26:40,470

54 EXO Earth candidates which is what we

717

00:26:45,649 --> 00:26:43,890

anticipate getting for Lubar a we that

718

00:26:48,590 --> 00:26:45,659

sample size would guarantee seeing at

719

00:26:50,480 --> 00:26:48,600

least one planet that truly has life or

720

00:26:53,720 --> 00:26:50,490

at least has you know remotely

721

00:26:55,820 --> 00:26:53,730

detectable bio signatures with 95%

722

00:26:57,680 --> 00:26:55,830

confidence if the frequency of inhabited

723

00:27:01,730 --> 00:26:57,690

planets is 5 percent of all candidates

724

00:27:03,320 --> 00:27:01,740

and as for Lou Barbie um so 28 exit

725

00:27:05,210 --> 00:27:03,330

Worth candidates would guarantee seeing

726
00:27:07,279 --> 00:27:05,220
at least one planet with life a 95

727
00:27:09,320 --> 00:27:07,289
percent confidence if their frequency of

728
00:27:12,919 --> 00:27:09,330
inhabited planets was 10 percent of all

729
00:27:15,169 --> 00:27:12,929
candidates so if life is rare large

730
00:27:17,029 --> 00:27:15,179
sample sizes will help you find it but

731
00:27:19,399 --> 00:27:17,039
what I think is also really powerful is

732
00:27:22,220 --> 00:27:19,409
that in the case of a null detection if

733
00:27:24,110 --> 00:27:22,230
you don't find anything Lavar would tell

734
00:27:24,990 --> 00:27:24,120
us just how alone we are in the universe

735
00:27:26,789 --> 00:27:25,000
so

736
00:27:28,560 --> 00:27:26,799
in the plenary session yesterday Sarah

737
00:27:30,539 --> 00:27:28,570
Walker was talking about you know trying

738
00:27:32,399 --> 00:27:30,549

to understand this very unknown

739

00:27:34,470 --> 00:27:32,409

parameter you know the probability of

740

00:27:36,029 --> 00:27:34,480

life in our universe as one of the sort

741

00:27:37,409 --> 00:27:36,039

of fundamental constants of our universe

742

00:27:39,330 --> 00:27:37,419

that we have no idea what the answer is

743

00:27:40,860 --> 00:27:39,340

to leave our is a kind of mission that

744

00:27:42,840 --> 00:27:40,870

would be able to start tackling these

745

00:27:44,850 --> 00:27:42,850

higher-order terms of the Drake Equation

746

00:27:46,110 --> 00:27:44,860

right that we don't know you know we

747

00:27:47,730 --> 00:27:46,120

don't know we'll have the frequency of

748

00:27:49,529 --> 00:27:47,740

habitable conditions are we don't know

749

00:27:51,120 --> 00:27:49,539

what the frequency of life is but in the

750

00:27:55,860 --> 00:27:51,130

case of a null detection we can at least

751

00:27:57,659 --> 00:27:55,870

place a useful upper limit all right so

752

00:27:59,190 --> 00:27:57,669

what exactly are we gonna do to search

753

00:28:01,980 --> 00:27:59,200

your value signatures and habitable

754

00:28:03,360 --> 00:28:01,990

conditions on exoplanets so what we'll

755

00:28:05,190 --> 00:28:03,370

do a course is we're gonna take spectra

756

00:28:06,779 --> 00:28:05,200

of their atmospheres so here's the

757

00:28:08,310 --> 00:28:06,789

spectrum of Earth or I should say of

758

00:28:09,930 --> 00:28:08,320

modern earth

759

00:28:11,700 --> 00:28:09,940

the first thing we'll probably search

760

00:28:13,470 --> 00:28:11,710

for will definitely the first thing

761

00:28:15,240 --> 00:28:13,480

we'll search for is water vapor because

762

00:28:16,980 --> 00:28:15,250

water is central to our definition of

763

00:28:19,320 --> 00:28:16,990

planetary habitability and it's really

764

00:28:21,270 --> 00:28:19,330

what the palatable zone concept is based

765

00:28:23,070 --> 00:28:21,280

upon right so by observing a bunch of

766

00:28:24,750 --> 00:28:23,080

planets in and Beyond the habitable zone

767

00:28:26,640 --> 00:28:24,760

and looking for water we'll even be able

768

00:28:30,180 --> 00:28:26,650

to test the concept of the habitable

769

00:28:32,970 --> 00:28:30,190

zone for planets that show signs of

770

00:28:34,740 --> 00:28:32,980

habitability we'll start to search for

771

00:28:35,970 --> 00:28:34,750

bio signatures now one important bio

772

00:28:37,799 --> 00:28:35,980

signature for at least modern eight

773

00:28:39,330 --> 00:28:37,809

earth is oxygen and it's photochemical

774

00:28:41,310 --> 00:28:39,340

by-product ozone as I'm sure you're

775

00:28:43,500 --> 00:28:41,320

familiar with right so oxygen is

776

00:28:46,080 --> 00:28:43,510

produced by oxygenic photosynthesis the

777

00:28:48,120 --> 00:28:46,090

dominant metabolism on our planet

778

00:28:50,039 --> 00:28:48,130

it's a metabolism that uses cosmically

779

00:28:54,149 --> 00:28:50,049

ubiquitous compounds to power itself

780

00:28:56,490 --> 00:28:54,159

like water and co2 and Starlight and it

781

00:28:58,140 --> 00:28:56,500

is such an energy yielding metabolism

782

00:29:00,149 --> 00:28:58,150

that perhaps it would be incentivized to

783

00:29:02,130 --> 00:29:00,159

evolve elsewhere so we definitely want

784

00:29:04,289 --> 00:29:02,140

to go after oxygen we can also go after

785

00:29:06,779 --> 00:29:04,299

ozone it's what a chemical byproduct on

786

00:29:08,760 --> 00:29:06,789

the strength of ozone features in the

787

00:29:10,890 --> 00:29:08,770

spectrum particularly in the UV scale

788

00:29:12,240 --> 00:29:10,900

not linearly with the amount of oxygen

789

00:29:14,399 --> 00:29:12,250

in the atmosphere and so they allow us

790

00:29:16,470 --> 00:29:14,409

to go after very low oxygen abundance

791

00:29:19,200 --> 00:29:16,480

atmospheres where the oxygen itself

792

00:29:21,000 --> 00:29:19,210

might not be detectable we could also

793

00:29:22,590 --> 00:29:21,010

look for bio signatures like methane now

794

00:29:26,070 --> 00:29:22,600

methane is a really interesting bio

795

00:29:27,930 --> 00:29:26,080

signature right because methane if we

796

00:29:29,310 --> 00:29:27,940

look just a couple planets down from us

797

00:29:30,810 --> 00:29:29,320

right so like Mars might have nothing

798

00:29:32,669 --> 00:29:30,820

and that's really exciting but I give

799

00:29:34,530 --> 00:29:32,679

you look beyond Mars it's Saturn's being

800

00:29:37,260 --> 00:29:34,540

tightened all right so Titan has an hour

801
00:29:39,900 --> 00:29:37,270
fear that's composed of about 3% methane

802
00:29:41,670 --> 00:29:39,910
Earth's atmospheres has about one part

803
00:29:43,020 --> 00:29:41,680
per million of methane yet in the

804
00:29:44,850 --> 00:29:43,030
context of Earth's atmosphere that

805
00:29:46,530 --> 00:29:44,860
methane we consider a bio signature

806
00:29:48,840 --> 00:29:46,540
because it's mostly produced by life in

807
00:29:50,700 --> 00:29:48,850
Titan's atmosphere most people would not

808
00:29:52,290 --> 00:29:50,710
tell you that that methane is a bio

809
00:29:54,780 --> 00:29:52,300
signature right like most

810
00:29:56,340 --> 00:29:54,790
astrobiologists would not say that the

811
00:29:58,590 --> 00:29:56,350
methane in Titan's atmosphere is being

812
00:30:00,540 --> 00:29:58,600
produced by life so we need to

813
00:30:03,030 --> 00:30:00,550

understand the context of these bio

814

00:30:04,890 --> 00:30:03,040

signatures or you know proposed bio

815

00:30:07,140 --> 00:30:04,900

signatures that we see in exoplanet

816

00:30:08,910 --> 00:30:07,150

atmospheres to understand whether

817

00:30:10,800 --> 00:30:08,920

they're more likely produced by life or

818

00:30:13,320 --> 00:30:10,810

whether they're more likely produced by

819

00:30:15,900 --> 00:30:13,330

non-life processes well we're actually

820

00:30:18,300 --> 00:30:15,910

gonna measure from a planetary spectrum

821

00:30:20,280 --> 00:30:18,310

are the gas concentrations but write the

822

00:30:21,930 --> 00:30:20,290

concentrations alone are not enough to

823

00:30:24,810 --> 00:30:21,940

tell us whether there's life there

824

00:30:26,460 --> 00:30:24,820

because you know you look at Titan Titan

825

00:30:28,440 --> 00:30:26,470

has a lot of methane that's probably not

826

00:30:29,880 --> 00:30:28,450

produced by life you look at earth or it

827

00:30:32,100 --> 00:30:29,890

has a tiny amount of methane and that's

828

00:30:33,600 --> 00:30:32,110

probably produced by life so what we

829

00:30:36,120 --> 00:30:33,610

have to do is we have to consider these

830

00:30:37,440 --> 00:30:36,130

concentrations in the context of the

831

00:30:39,390 --> 00:30:37,450

environment and the atmosphere that

832

00:30:40,950 --> 00:30:39,400

they're found in as well as the context

833

00:30:42,780 --> 00:30:40,960

of the star planet interactions that are

834

00:30:44,220 --> 00:30:42,790

going on because the star the

835

00:30:45,720 --> 00:30:44,230

photochemistry from the star can

836

00:30:47,430 --> 00:30:45,730

dramatically change the atmosphere

837

00:30:49,590 --> 00:30:47,440

solovar will do this right it's gonna

838

00:30:51,480 --> 00:30:49,600

observe as much contacts from the planet

839

00:30:53,700 --> 00:30:51,490

as we can and it's also going to observe

840

00:30:56,250 --> 00:30:53,710

spectra of the stars because we must

841

00:30:58,050 --> 00:30:56,260

understand the stars to understand the

842

00:31:00,390 --> 00:30:58,060

photochemical reactions that might be

843

00:31:02,400 --> 00:31:00,400

occurring their atmospheres we could

844

00:31:04,950 --> 00:31:02,410

then feed these into atmospheric models

845

00:31:07,050 --> 00:31:04,960

to try to predict the production rates

846

00:31:09,000 --> 00:31:07,060

that you need in order to produce the

847

00:31:12,990 --> 00:31:09,010

gas at the concentrations that we see in

848

00:31:14,910 --> 00:31:13,000

the planetary atmosphere and this is for

849

00:31:17,490 --> 00:31:14,920

us the holy grail because production

850

00:31:20,220 --> 00:31:17,500

rates that cannot be explained or

851
00:31:22,950 --> 00:31:20,230
perhaps I should say are unlikely to be

852
00:31:26,250 --> 00:31:22,960
explainable through abiotic processes

853
00:31:28,380 --> 00:31:26,260
alone point to biology so if you see a

854
00:31:30,600 --> 00:31:28,390
planet like Titan where you don't need

855
00:31:32,430 --> 00:31:30,610
extremely rapid production rates to

856
00:31:34,710 --> 00:31:32,440
produce that methane in that context

857
00:31:36,720 --> 00:31:34,720
that's much much less likely to be

858
00:31:38,630 --> 00:31:36,730
produced by life as opposed to methane

859
00:31:40,820 --> 00:31:38,640
in the context of Earth's atmosphere

860
00:31:43,820 --> 00:31:40,830
and so this is the game that we're gonna

861
00:31:45,110 --> 00:31:43,830
play in the future but of course we know

862
00:31:46,280 --> 00:31:45,120
from Earth's history that there's more

863
00:31:47,630 --> 00:31:46,290

than one way to make an earth right I've

864

00:31:49,130 --> 00:31:47,640

been talking about modern ears and

865

00:31:52,370 --> 00:31:49,140

modern ears is a great starting point

866

00:31:54,200 --> 00:31:52,380

but Earth has changed dramatically over

867

00:31:55,880 --> 00:31:54,210

geological history and I think one of

868

00:31:57,500 --> 00:31:55,890

the really powerful things about leVoir

869

00:32:00,440 --> 00:31:57,510

as well as the Havoc's mission concept

870

00:32:02,240 --> 00:32:00,450

is that we've been thinking about how to

871

00:32:04,340 --> 00:32:02,250

detect bio signatures for all of us

872

00:32:06,530 --> 00:32:04,350

inhabited history so one of the explicit

873

00:32:08,840 --> 00:32:06,540

science goals of lavars we want to be

874

00:32:10,100 --> 00:32:08,850

able to detect life on Earth for as long

875

00:32:11,690 --> 00:32:10,110

as Earth's was habitable and so we've

876

00:32:14,480 --> 00:32:11,700

been thinking a lot about bio signatures

877

00:32:16,940 --> 00:32:14,490

through time so for modern a earth right

878

00:32:19,130 --> 00:32:16,950

oxygen is hugely abundant in our

879

00:32:20,659 --> 00:32:19,140

atmosphere and is easy to detect but if

880

00:32:22,310 --> 00:32:20,669

we go back to the Archaean oxygen was

881

00:32:24,230 --> 00:32:22,320

not detectable right and then the Hadean

882

00:32:25,789 --> 00:32:24,240

as well oxygen levels were extremely low

883

00:32:27,980 --> 00:32:25,799

so you have to think about other kinds

884

00:32:29,419 --> 00:32:27,990

of bio signatures and then for the mid

885

00:32:31,100 --> 00:32:29,429

Proterozoic there have been studies that

886

00:32:32,990 --> 00:32:31,110

have suggested that oxygen levels may

887

00:32:34,669 --> 00:32:33,000

have been very low potentially as low as

888

00:32:37,250 --> 00:32:34,679

0.1 percent of the modern atmospheric

889

00:32:38,960 --> 00:32:37,260

level and so if you have oxygen levels

890

00:32:41,240 --> 00:32:38,970

that low you can't actually detect the

891

00:32:43,700 --> 00:32:41,250

oxygen in itself even though it's in the

892

00:32:45,620 --> 00:32:43,710

atmosphere so you need to think about

893

00:32:47,390 --> 00:32:45,630

these false negative planets as well

894

00:32:51,289 --> 00:32:47,400

that have life that life might be

895

00:32:53,150 --> 00:32:51,299

challenging to detect for a planet with

896

00:32:54,650 --> 00:32:53,160

an anoxic atmosphere um there's been a

897

00:32:55,909 --> 00:32:54,660

lot of work by various people including

898

00:32:57,770 --> 00:32:55,919

Josh christine's and Taunton who

899

00:32:59,450 --> 00:32:57,780

suggested that if you see a lot of

900

00:33:01,760 --> 00:32:59,460

methane together with a lot of co2 that

901
00:33:03,440 --> 00:33:01,770
implies rapid methane production that's

902
00:33:05,000 --> 00:33:03,450
indicative of life and so that's

903
00:33:09,530 --> 00:33:05,010
something we would want to go after for

904
00:33:11,299 --> 00:33:09,540
these antioxidant as it which might have

905
00:33:14,690 --> 00:33:11,309
had very low oxygen levels

906
00:33:17,480 --> 00:33:14,700
you go after O₃ in the UV so the O₃

907
00:33:19,250 --> 00:33:17,490
feature in the UV is the strongest ozone

908
00:33:20,630 --> 00:33:19,260
feature across the entire spectral range

909
00:33:22,549 --> 00:33:20,640
and it's really important to access that

910
00:33:27,230 --> 00:33:22,559
feature for these very low oxygen

911
00:33:30,049 --> 00:33:27,240
abundance atmospheres alright so I just

912
00:33:31,940 --> 00:33:30,059
want to conclude by saying that with the

913
00:33:34,070 --> 00:33:31,950

large sample size enabled by a mission

914

00:33:35,810 --> 00:33:34,080

like leVoir we'll be able to maximize

915

00:33:37,850 --> 00:33:35,820

our chances of discovering if we're

916

00:33:39,650 --> 00:33:37,860

alone in the universe and discovering if

917

00:33:41,360 --> 00:33:39,660

there are detectable bio signatures on

918

00:33:43,779 --> 00:33:41,370

planets that are orbiting nearby stars

919

00:33:45,909 --> 00:33:43,789

and in the case of annulled

920

00:33:47,409 --> 00:33:45,919

tection will finally know just how alone

921

00:33:49,210 --> 00:33:47,419

we are in the universe and we'll begin

922

00:33:51,430 --> 00:33:49,220

to be able to place an upper limit on

923

00:33:57,460 --> 00:33:51,440

how frequently life and habitability

924

00:33:59,080 --> 00:33:57,470

occurs and lastly because of the number

925

00:34:00,820 --> 00:33:59,090

of planets in the diversity of planets

926

00:34:02,710 --> 00:34:00,830

the Lavar will sample we'll be able to

927

00:34:04,810 --> 00:34:02,720

start to place our whole solar system in

928

00:34:07,690 --> 00:34:04,820

the context of the types of planets that

929

00:34:08,889 --> 00:34:07,700

are possible elsewhere I'm at a time and

930

00:34:11,349 --> 00:34:08,899

I'll just leave you with this beautiful

931

00:34:13,359 --> 00:34:11,359

quote from the NASA at the neck the

932

00:34:15,159 --> 00:34:13,369

National Academy of Sciences exoplanet

933

00:34:16,809 --> 00:34:15,169

science strategy report the search for

934

00:34:18,760 --> 00:34:16,819

life on other worlds is both a profound

935

00:34:20,649 --> 00:34:18,770

and profoundly difficult endeavor but I

936

00:34:29,490 --> 00:34:20,659

think we the astrobiology community are

937

00:34:33,819 --> 00:34:32,079

Thank You Jarrah next up we'll have

938

00:34:35,409 --> 00:34:33,829

Scott Gowdy from The Ohio State

939

00:34:38,680 --> 00:34:35,419

University who is also one of the

940

00:34:40,450 --> 00:34:38,690

co-chairs I know how to do it it was

941

00:34:44,770 --> 00:34:40,460

also one of the coaches of the Havoc's

942

00:34:47,319 --> 00:34:44,780

mission concept Scott alright first I'd

943

00:34:49,450 --> 00:34:47,329

like to thank Sean and Vicki and Karl

944

00:34:52,690 --> 00:34:49,460

for inviting me to give a talk on have X

945

00:34:54,970 --> 00:34:52,700

I will preface this by saying I am NOT

946

00:34:56,889 --> 00:34:54,980

an astrobiologist although Sean keeps

947

00:34:59,289 --> 00:34:56,899

trying to indoctrinate me to becoming

948

00:35:03,789 --> 00:34:59,299

one so I guess I'm starting to become

949

00:35:06,220 --> 00:35:03,799

one I want to thank my I want to thank

950

00:35:08,740 --> 00:35:06,230

my co leads on this mission the Koch

951
00:35:12,089 --> 00:35:08,750
community chair is a Sara Seager the

952
00:35:17,530 --> 00:35:12,099
mission is based out of JPL so so and

953
00:35:19,599 --> 00:35:17,540
sorry about that and and so Bertrand

954
00:35:25,030 --> 00:35:19,609
Medicine Alena Kiesling Keith Warfield

955
00:35:26,620 --> 00:35:25,040
are all our leaders at JPL keith is our

956
00:35:29,710 --> 00:35:26,630
center study manager and keeps us in

957
00:35:31,270 --> 00:35:29,720
line and this is our stdt this is all

958
00:35:33,520 --> 00:35:31,280
the way back through over three years

959
00:35:34,870 --> 00:35:33,530
ago from our first meeting there are

960
00:35:36,940 --> 00:35:34,880
pictures of people that weren't able to

961
00:35:38,950 --> 00:35:36,950
attend or added later and then also

962
00:35:41,289 --> 00:35:38,960
people from the international community

963
00:35:43,390 --> 00:35:41,299

that are observers on this so we have a

964

00:35:49,599 --> 00:35:43,400

relatively small team compared to some

965

00:35:57,470 --> 00:35:54,769

know it's there you go okay so we have X

966

00:35:59,420 --> 00:35:57,480

has three basic science goals one is to

967

00:36:01,609 --> 00:35:59,430

seek out nearby worlds and explore their

968

00:36:03,769 --> 00:36:01,619

habitability the second is a map nearby

969

00:36:06,049 --> 00:36:03,779

planetary systems so a small subset of

970

00:36:07,069 --> 00:36:06,059

our nearest neighbors and explore the

971

00:36:09,890 --> 00:36:07,079

diversity of the worlds that they

972

00:36:12,620 --> 00:36:09,900

contain in as its deep as possible

973

00:36:15,829 --> 00:36:12,630

and finally we have a third goal which

974

00:36:17,990 --> 00:36:15,839

is to enable new explorations by

975

00:36:20,539 --> 00:36:18,000

extending our reach from the UV to the

976

00:36:23,390 --> 00:36:20,549

near IR so this is non direct imaging

977

00:36:27,319 --> 00:36:23,400

exoplanet science and it constitutes a

978

00:36:29,630 --> 00:36:27,329

50% of our science of other time we

979

00:36:31,400 --> 00:36:29,640

expect for our prime mission so I'd like

980

00:36:33,890 --> 00:36:31,410

you to walk away from here understanding

981

00:36:36,620 --> 00:36:33,900

that habits is not just a direct imaging

982

00:36:41,599 --> 00:36:36,630

mission okay so in terms of our first

983

00:36:43,789 --> 00:36:41,609

science topic we saw achieving the

984

00:36:45,230 --> 00:36:43,799

direct detection of it so first I want

985

00:36:46,759 --> 00:36:45,240

us to take a step back and mention

986

00:36:48,620 --> 00:36:46,769

something that's a very important point

987

00:36:51,170 --> 00:36:48,630

this is the first time in human history

988

00:36:53,299 --> 00:36:51,180

that we have the scientific knowledge

989

00:36:55,249 --> 00:36:53,309

and the technological capabilities are

990

00:36:57,380 --> 00:36:55,259

within shouting distance of having the

991

00:36:59,930 --> 00:36:57,390

technological capabilities of being able

992

00:37:01,609 --> 00:36:59,940

to directly detect an earth-like planet

993

00:37:04,880 --> 00:37:01,619

orbiting a sun-like star now we heard

994

00:37:07,400 --> 00:37:04,890

from Vicki and Kat and we'll hear from

995

00:37:09,380 --> 00:37:07,410

Kevin about how you can do this for

996

00:37:11,720 --> 00:37:09,390

small planets orbiting M dwarfs this is

997

00:37:13,960 --> 00:37:11,730

commonly called the M dwarf Opportunity

998

00:37:17,630 --> 00:37:13,970

or I like to call it small black shadows

999

00:37:19,640 --> 00:37:17,640

that is the the the the fast track and

1000

00:37:21,769 --> 00:37:19,650

certainly something we should do but we

1001
00:37:23,329 --> 00:37:21,779
should also search for potentially

1002
00:37:25,609 --> 00:37:23,339
habitable worlds and maybe even in

1003
00:37:27,499 --> 00:37:25,619
habitable worlds around sun-like stars

1004
00:37:29,660 --> 00:37:27,509
using direct imaging in the reflected

1005
00:37:31,999 --> 00:37:29,670
optical and eventually direct imaging in

1006
00:37:34,009 --> 00:37:32,009
the mid Fred that requires us to go to

1007
00:37:35,779 --> 00:37:34,019
space and this is the first time we've

1008
00:37:37,400 --> 00:37:35,789
been able to do that we may have thought

1009
00:37:38,539 --> 00:37:37,410
we were able to do that 10 years ago but

1010
00:37:40,999 --> 00:37:38,549
it turns out that that's not actually

1011
00:37:42,410 --> 00:37:41,009
true and I can talk to you during the

1012
00:37:43,940 --> 00:37:42,420
discussion session for what we've

1013
00:37:46,039 --> 00:37:43,950

learned in the last 10 years that

1014

00:37:47,630 --> 00:37:46,049

enables us to be possible the

1015

00:37:49,430 --> 00:37:47,640

requirements are that we have to reach

1016

00:37:51,220 --> 00:37:49,440

10 to the minus 10 contrast because

1017

00:37:54,499 --> 00:37:51,230

that's the flux ratio of Earth to Sun

1018

00:37:57,440 --> 00:37:54,509

with a resolution and resolve the earth

1019

00:38:02,370 --> 00:37:57,450

from that That star if that star is at

1020

00:38:03,930 --> 00:38:02,380

15 parsecs to 0.06 arc seconds

1021

00:38:06,089 --> 00:38:03,940

and so that's what you can see right

1022

00:38:08,339 --> 00:38:06,099

here and that's the capabilities that

1023

00:38:09,930 --> 00:38:08,349

have X is really try to achieve another

1024

00:38:11,160 --> 00:38:09,940

point I'd like to make is it's common

1025

00:38:13,530 --> 00:38:11,170

wisdom that you need a 10 meter

1026

00:38:15,150 --> 00:38:13,540

telescope to do this it's not true

1027

00:38:17,280 --> 00:38:15,160

we now know that the frequency of

1028

00:38:18,870 --> 00:38:17,290

potentially habitable worlds in the

1029

00:38:20,640 --> 00:38:18,880

habitable zone is high enough that you

1030

00:38:22,530 --> 00:38:20,650

can do this with smaller telescopes so

1031

00:38:24,180 --> 00:38:22,540

that's great of course you won't get the

1032

00:38:26,670 --> 00:38:24,190

sample sizes of luke war and we'll talk

1033

00:38:28,740 --> 00:38:26,680

a little bit more about that and so

1034

00:38:30,140 --> 00:38:28,750

these dots show the realization of the

1035

00:38:33,089 --> 00:38:30,150

kinds of planets abducts would be

1036

00:38:35,220 --> 00:38:33,099

sensitive to now we use two star light

1037

00:38:37,650 --> 00:38:35,230

suppression techniques one is a

1038

00:38:39,780 --> 00:38:37,660

coronagraph so this is just the simple

1039

00:38:41,790 --> 00:38:39,790

idea of blocking the light from the star

1040

00:38:43,349 --> 00:38:41,800

after it enters the telescope pupil but

1041

00:38:45,300 --> 00:38:43,359

because of diffraction effects

1042

00:38:47,190 --> 00:38:45,310

imperfection of the optics you have to

1043

00:38:49,470 --> 00:38:47,200

use fancy optics to get rid of that

1044

00:38:52,530 --> 00:38:49,480

excess light and detect the planet in

1045

00:38:54,930 --> 00:38:52,540

one part per 10 billion the other way is

1046

00:38:57,660 --> 00:38:54,940

to do it use an external culture this in

1047

00:39:00,030 --> 00:38:57,670

this case we also call star shade so

1048

00:39:01,349 --> 00:39:00,040

this in case there habits is a 52 meters

1049

00:39:03,540 --> 00:39:01,359

star shade roughly the size of a

1050

00:39:05,010 --> 00:39:03,550

baseball diamond flying it roughly

1051
00:39:06,990 --> 00:39:05,020
seventy six thousand kilometers away

1052
00:39:08,790 --> 00:39:07,000
from the telescope you have to

1053
00:39:11,250 --> 00:39:08,800
manufacture the edges to a precision of

1054
00:39:12,810 --> 00:39:11,260
roughly a micron it has to unfurl to a

1055
00:39:15,780 --> 00:39:12,820
precision of roughly a millimeter and

1056
00:39:17,700 --> 00:39:15,790
asked to remained aligned to roughly one

1057
00:39:19,710 --> 00:39:17,710
meter now all this may sound fairly

1058
00:39:20,760 --> 00:39:19,720
terrifying but believe it or not we've

1059
00:39:22,940 --> 00:39:20,770
actually advanced that these

1060
00:39:25,890 --> 00:39:22,950
technologies to the point where they're

1061
00:39:26,820 --> 00:39:25,900
called crl 4 which means that they're

1062
00:39:28,680 --> 00:39:26,830
not vaporware

1063
00:39:30,390 --> 00:39:28,690

these are real technologies that have

1064

00:39:34,140 --> 00:39:30,400

that are well on their way to being

1065

00:39:35,370 --> 00:39:34,150

ready to be selected for our mission the

1066

00:39:36,390 --> 00:39:35,380

nice thing about a chronograph and

1067

00:39:38,490 --> 00:39:36,400

starshade is that they're very

1068

00:39:40,680 --> 00:39:38,500

compatible so a chronograph is very

1069

00:39:44,609 --> 00:39:40,690

nimble allows you to quickly look at

1070

00:39:46,770 --> 00:39:44,619

many stars and find potential candidates

1071

00:39:48,450 --> 00:39:46,780

for earth-like planets take their colors

1072

00:39:50,339 --> 00:39:48,460

get their orbits see if they are indeed

1073

00:39:52,260 --> 00:39:50,349

in the habitable zone and if they are

1074

00:39:55,320 --> 00:39:52,270

then you slew your star shade there

1075

00:39:57,450 --> 00:39:55,330

which which allows you to get is

1076
00:40:00,690 --> 00:39:57,460
basically a chromatic allows you to get

1077
00:40:02,250 --> 00:40:00,700
broadband spectra from 0.2 to 1.8

1078
00:40:04,349 --> 00:40:02,260
microns so you can look for all those

1079
00:40:06,870 --> 00:40:04,359
beautiful features that we heard yah to

1080
00:40:09,180 --> 00:40:06,880
talk about but the star shade is slow

1081
00:40:11,070 --> 00:40:09,190
you could only take several weeks to go

1082
00:40:12,960 --> 00:40:11,080
from target to target and its fuel

1083
00:40:14,380 --> 00:40:12,970
limited so you have to it's a it's a

1084
00:40:16,360 --> 00:40:14,390
resource you have to

1085
00:40:18,490 --> 00:40:16,370
it's very valuable so you can't use it

1086
00:40:20,140 --> 00:40:18,500
all the time but by combining these two

1087
00:40:22,330 --> 00:40:20,150
methods we can both find the planets

1088
00:40:25,270 --> 00:40:22,340

determine their orbits and then get

1089

00:40:26,980 --> 00:40:25,280

broadband spectrum oh no graphs on the

1090

00:40:28,570 --> 00:40:26,990

other hand are fairly chromatic so you

1091

00:40:32,140 --> 00:40:28,580

have to get spectra in sort of very

1092

00:40:33,820 --> 00:40:32,150

small chunks of roughly 20% and so

1093

00:40:35,230 --> 00:40:33,830

therefore it's very expensive or you

1094

00:40:37,570 --> 00:40:35,240

have the coronagraph with many channels

1095

00:40:42,040 --> 00:40:37,580

which is also expensive in terms of cost

1096

00:40:43,570 --> 00:40:42,050

not time okay so well basic ideas we're

1097

00:40:46,150 --> 00:40:43,580

gonna use the coronagraph to survey for

1098

00:40:47,560 --> 00:40:46,160

roughly 50 stars for potentially

1099

00:40:49,090 --> 00:40:47,570

habitable world we're gonna do this

1100

00:40:51,730 --> 00:40:49,100

vetting process to find the most

1101
00:40:53,350 --> 00:40:51,740
promising ones and those will be studied

1102
00:40:55,450 --> 00:40:53,360
then with a chronograph in a star shade

1103
00:40:57,070 --> 00:40:55,460
and of course this is the holy grail of

1104
00:40:59,170 --> 00:40:57,080
what we expect to get this is a

1105
00:41:01,360 --> 00:40:59,180
simulation of what habits can do with

1106
00:41:03,370 --> 00:41:01,370
about oh I don't know 10 days of

1107
00:41:05,530 --> 00:41:03,380
observations it turns out Earth's are

1108
00:41:09,880 --> 00:41:05,540
like earth-like planets or faint around

1109
00:41:13,990 --> 00:41:09,890
a real star beta cvn it's a G 0 for a

1110
00:41:15,820 --> 00:41:14,000
star at 8.4 parsecs and this gives us a

1111
00:41:17,140 --> 00:41:15,830
we set the requirement for the

1112
00:41:20,110 --> 00:41:17,150
signal-to-noise so that we can detect

1113
00:41:22,690 --> 00:41:20,120

the oxygenated band at point 6 7 6

1114

00:41:25,270 --> 00:41:22,700
microns with a signal-to-noise of 10 at

1115

00:41:27,040 --> 00:41:25,280
a resolution of 140 and that allows us

1116

00:41:29,170 --> 00:41:27,050
to get a spectrum that looks like this

1117

00:41:30,880 --> 00:41:29,180
so you can see we can see all those

1118

00:41:32,860 --> 00:41:30,890
beautiful features that is signal not

1119

00:41:33,370 --> 00:41:32,870
only that this world may be potentially

1120

00:41:36,130 --> 00:41:33,380
abotobble

1121

00:41:37,570 --> 00:41:36,140
but also inhabited now unfortunately

1122

00:41:39,640 --> 00:41:37,580
with Havoc's we just don't have the

1123

00:41:41,830 --> 00:41:39,650
aperture to get methane which would be

1124

00:41:45,190 --> 00:41:41,840
great because if we get oxygen methane

1125

00:41:47,620 --> 00:41:45,200
but what we do have but we but we are

1126

00:41:49,390 --> 00:41:47,630

and not so naive to think that all

1127

00:41:51,520 --> 00:41:49,400

earth-like planets even if they're

1128

00:41:53,230 --> 00:41:51,530

inhabited or habitable are going to look

1129

00:41:55,000 --> 00:41:53,240

like modern-day earth since modern day

1130

00:41:57,190 --> 00:41:55,010

or thought only looked like it did for a

1131

00:41:59,920 --> 00:41:57,200

relatively small fraction of time so

1132

00:42:02,590 --> 00:41:59,930

we're also looking as Gianna mentioned

1133

00:42:05,260 --> 00:42:02,600

at the earth over time and bio

1134

00:42:06,760 --> 00:42:05,270

signatures over time and I won't belabor

1135

00:42:09,340 --> 00:42:06,770

this point this is just another version

1136

00:42:11,290 --> 00:42:09,350

of the plot that giada showed except now

1137

00:42:12,850 --> 00:42:11,300

I'm showing the actual simulated spectra

1138

00:42:15,250 --> 00:42:12,860

from different phases of the Earth's

1139

00:42:17,380 --> 00:42:15,260

history and all of these are readily we

1140

00:42:19,870 --> 00:42:17,390

can detect the bio signatures of all

1141

00:42:22,540 --> 00:42:19,880

that Giada mentions for basically all of

1142

00:42:24,430 --> 00:42:22,550

these phases quite readily so that's

1143

00:42:26,620 --> 00:42:24,440

very powerful both for habits and

1144

00:42:28,630 --> 00:42:26,630

or I want to make sure that people don't

1145

00:42:30,670 --> 00:42:28,640

get wrapped around too much this idea of

1146

00:42:33,880 --> 00:42:30,680

a to earth or the fraction of stars in

1147

00:42:36,220 --> 00:42:33,890

the habitable zone as we all know the

1148

00:42:39,010 --> 00:42:36,230

habitable zone and how and how large it

1149

00:42:42,400 --> 00:42:39,020

would spans in terms of effective

1150

00:42:45,069 --> 00:42:42,410

luminosity or radiant irradiance and the

1151

00:42:46,630 --> 00:42:45,079

size of the planet is controversial we

1152

00:42:48,849 --> 00:42:46,640

have some ideas those are based on

1153

00:42:51,040 --> 00:42:48,859

well-founded physical principles but in

1154

00:42:53,050 --> 00:42:51,050

truth yes thank you we don't actually

1155

00:42:55,300 --> 00:42:53,060

know what that is but so what's really

1156

00:42:57,790 --> 00:42:55,310

nice is that even though we only have a

1157

00:43:00,010 --> 00:42:57,800

small relatively small number of dots in

1158

00:43:01,839 --> 00:43:00,020

the habitable zone in the smart box we

1159

00:43:03,640 --> 00:43:01,849

have lots of dots around it so we can

1160

00:43:05,980 --> 00:43:03,650

begin to try to empirically define the

1161

00:43:08,349 --> 00:43:05,990

habitable zone okay

1162

00:43:09,819 --> 00:43:08,359

so real quickly we also have a sample of

1163

00:43:11,890 --> 00:43:09,829

eight stars that we're gonna get very

1164

00:43:13,809 --> 00:43:11,900

deep family portraits with the star

1165

00:43:15,490 --> 00:43:13,819

shade star shade has a wide field of

1166

00:43:17,380 --> 00:43:15,500

view so you can detect almost all the

1167

00:43:19,750 --> 00:43:17,390

planets and even dust belts in the

1168

00:43:21,339 --> 00:43:19,760

system and you can get simultaneous

1169

00:43:22,960 --> 00:43:21,349

spectra of all of them within two arc

1170

00:43:24,730 --> 00:43:22,970

seconds and since you're getting

1171

00:43:26,500 --> 00:43:24,740

signal-to-noise that are reasonably high

1172

00:43:28,089 --> 00:43:26,510

for earth-like planets you're gonna get

1173

00:43:30,819 --> 00:43:28,099

very high signal-to-noise for much

1174

00:43:32,410 --> 00:43:30,829

larger planets that are much brighter so

1175

00:43:34,089 --> 00:43:32,420

you can get complete family portraits

1176

00:43:35,680 --> 00:43:34,099

and start to ask about questions about

1177

00:43:38,050 --> 00:43:35,690

if you have a potentially habitable

1178

00:43:40,359 --> 00:43:38,060

planet does it have does it need to have

1179

00:43:44,140 --> 00:43:40,369

a jupiter-mass planet around around it

1180

00:43:46,990 --> 00:43:44,150

or not okay so these are eight targets

1181

00:43:49,059 --> 00:43:47,000

and I just mentioned them because it's

1182

00:43:50,980 --> 00:43:49,069

really nice we think Hollywood because

1183

00:43:53,170 --> 00:43:50,990

we now know that about roughly half of

1184

00:43:56,410 --> 00:43:53,180

these are already inhabited so that

1185

00:43:58,420 --> 00:43:56,420

means we're ensured of success okay this

1186

00:43:59,890 --> 00:43:58,430

is our yields they're not as large as

1187

00:44:02,680 --> 00:43:59,900

new are i'll admit that right off the

1188

00:44:04,780 --> 00:44:02,690

but there's eight potentially habitable

1189

00:44:07,000 --> 00:44:04,790

planets and/or dots in that little

1190

00:44:08,440 --> 00:44:07,010

habitable zone box but there's plenty of

1191

00:44:09,940 --> 00:44:08,450

dots around that and again so we can

1192

00:44:12,309 --> 00:44:09,950

empirically define the habitable zone

1193

00:44:14,290 --> 00:44:12,319

and there are dozens to hundreds of

1194

00:44:16,690 --> 00:44:14,300

other planets which will have carat be

1195

00:44:18,880 --> 00:44:16,700

fully characterized with spectra and

1196

00:44:21,520 --> 00:44:18,890

orbits so we can do comparative

1197

00:44:23,200 --> 00:44:21,530

exoplanet ology and so even if we do get

1198

00:44:25,030 --> 00:44:23,210

this no results we'll have an

1199

00:44:28,089 --> 00:44:25,040

interesting upper limit not as strong as

1200

00:44:30,640 --> 00:44:28,099

leVoir but we will also have this vast

1201
00:44:32,470 --> 00:44:30,650
array of comparative exploit exoplanet

1202
00:44:34,750 --> 00:44:32,480
ology so I don't really have time to

1203
00:44:36,370 --> 00:44:34,760
talk about the third goal I will mention

1204
00:44:38,279 --> 00:44:36,380
that we have two other instruments that

1205
00:44:41,429 --> 00:44:38,289
are UV spectrograph

1206
00:44:44,339 --> 00:44:41,439
imager and a infrared spectrograph an

1207
00:44:46,079 --> 00:44:44,349
imager that have capabilities that well

1208
00:44:48,689 --> 00:44:46,089
exceed that of HST

1209
00:44:51,449 --> 00:44:48,699
again we expect 50% of our time to be

1210
00:44:53,370 --> 00:44:51,459
towards Geo programs so that can be any

1211
00:44:55,349 --> 00:44:53,380
number of things here's a just a small

1212
00:44:56,939 --> 00:44:55,359
laundry list I'm just gonna speed

1213
00:44:59,489 --> 00:44:56,949

through 3 things that you think you

1214

00:45:02,459 --> 00:44:59,499

might be interested in one we can get a

1215

00:45:05,729 --> 00:45:02,469

transmission spectroscopy of planets not

1216

00:45:08,640 --> 00:45:05,739

just giant planets but also potentially

1217

00:45:10,819 --> 00:45:08,650

rocky planets we can look for we'll get

1218

00:45:14,159 --> 00:45:10,829

high resolution so sorry let me go back

1219

00:45:16,169 --> 00:45:14,169

this is a this the top is an image

1220

00:45:17,759 --> 00:45:16,179

simulated image of habits of Neptune

1221

00:45:19,380 --> 00:45:17,769

another little black dot is our

1222

00:45:21,449 --> 00:45:19,390

resolution on an element the bottom is

1223

00:45:23,159 --> 00:45:21,459

the image from Voyager 2 so we could

1224

00:45:25,409 --> 00:45:23,169

measure wind speeds and things like that

1225

00:45:27,329 --> 00:45:25,419

and finally we can look for aurora on

1226

00:45:28,919 --> 00:45:27,339

the ice giants which as we know the

1227

00:45:30,689 --> 00:45:28,929

magnetic field of the ice giants are

1228

00:45:32,370 --> 00:45:30,699

strange and we don't know very much

1229

00:45:34,109 --> 00:45:32,380

about the solar wind interaction with

1230

00:45:36,299 --> 00:45:34,119

these planets which is important for

1231

00:45:38,249 --> 00:45:36,309

understanding mass loss which we've

1232

00:45:40,709 --> 00:45:38,259

learned from Kepler is a very important

1233

00:45:42,779 --> 00:45:40,719

of a physical process that happens at

1234

00:45:44,880 --> 00:45:42,789

least for shorter period planets and so

1235

00:45:46,829 --> 00:45:44,890

I will leave that this up here I haven't

1236

00:45:49,499 --> 00:45:46,839

said anything about our architecture

1237

00:45:50,969 --> 00:45:49,509

anyway you can read about it if you want

1238

00:45:54,809 --> 00:45:50,979

more information look for our final

1239

00:45:57,839 --> 00:45:54,819

report and end or email me and with that

1240

00:45:59,519 --> 00:45:57,849

I'm gonna ask Giada to come up we're

1241

00:46:02,279 --> 00:45:59,529

gonna use a little bit of the discussion

1242

00:46:05,489 --> 00:46:02,289

time because to present one more slide

1243

00:46:07,589 --> 00:46:05,499

so Louvre Oh Lavar and Havoc's the teams

1244

00:46:10,409 --> 00:46:07,599

have often are often asked pretty much

1245

00:46:12,299 --> 00:46:10,419

at every talk we give what is the

1246

00:46:14,729 --> 00:46:12,309

similarities or differences or how at

1247

00:46:16,409 --> 00:46:14,739

your two studies related so we created

1248

00:46:19,529 --> 00:46:16,419

this slide to answer that question the

1249

00:46:21,179 --> 00:46:19,539

have X and lavars team teams and links

1250

00:46:25,259 --> 00:46:21,189

and origins have we've already already

1251
00:46:26,909 --> 00:46:25,269
mentioned have spent over three years

1252
00:46:29,640 --> 00:46:26,919
nearly three and a half years of many

1253
00:46:31,409 --> 00:46:29,650
thousands of person hours and millions

1254
00:46:34,169 --> 00:46:31,419
of dollars investing in these large

1255
00:46:36,120 --> 00:46:34,179
strategic mission concepts to develop

1256
00:46:38,539 --> 00:46:36,130
them to the level fidelity that

1257
00:46:41,999 --> 00:46:38,549
basically has never been seen before

1258
00:46:43,319 --> 00:46:42,009
I'll turn it over to you to see that no

1259
00:46:43,690 --> 00:46:43,329
it's because I'm too short from over

1260
00:46:46,210 --> 00:46:43,700
there

1261
00:46:47,740 --> 00:46:46,220
I'm so together Louvre Oran Havoc's have

1262
00:46:49,420 --> 00:46:47,750
been whirring together since the start

1263
00:46:52,270 --> 00:46:49,430

of these two studies we're going to

1264

00:46:53,740 --> 00:46:52,280

present between these two studies 11

1265

00:46:55,780 --> 00:46:53,750

different architectures to the decay

1266

00:46:58,930 --> 00:46:55,790

toll which will help to you know provide

1267

00:47:00,640 --> 00:46:58,940

a buffet of different options for the

1268

00:47:03,190 --> 00:47:00,650

decay doll to choose from depending on

1269

00:47:04,559 --> 00:47:03,200

you know what the landscape looks like

1270

00:47:07,150 --> 00:47:04,569

when they're making their decisions

1271

00:47:08,710 --> 00:47:07,160

we've been collaborating for a long time

1272

00:47:10,839 --> 00:47:08,720

and we both agree that a joint

1273

00:47:13,030 --> 00:47:10,849

astrophysics exoplanet UV optical near

1274

00:47:15,960 --> 00:47:13,040

IR observatory provides a bold and

1275

00:47:26,530 --> 00:47:15,970

achievable vision for space astronomy

1276

00:47:30,370 --> 00:47:28,120

and just on that note also point out

1277

00:47:31,359 --> 00:47:30,380

that the exoplanet folks on both teams

1278

00:47:32,950 --> 00:47:31,369

have been working with each other and

1279

00:47:34,120 --> 00:47:32,960

with the origins team as well to think

1280

00:47:36,010 --> 00:47:34,130

about what habitability and bio

1281

00:47:38,560 --> 00:47:36,020

signatures we might get with those three

1282

00:47:40,839 --> 00:47:38,570

missions the last mission concept we did

1283

00:47:42,490 --> 00:47:40,849

try to get someone from links here we

1284

00:47:44,890 --> 00:47:42,500

could not for various travel conflicts

1285

00:47:46,690 --> 00:47:44,900

that were in place before we made our

1286

00:47:48,070 --> 00:47:46,700

invitations so instead of some from the

1287

00:47:50,500 --> 00:47:48,080

links team we're gonna have my esteemed

1288

00:47:52,660 --> 00:47:50,510

co-chair and the chief scientists of the

1289

00:47:55,000 --> 00:47:52,670

exoplanet exploration program office

1290

00:48:02,079 --> 00:47:55,010

Carl Snapple felt talk about what links

1291

00:48:03,700 --> 00:48:02,089

can do for exoplanet science Carl ok

1292

00:48:05,260 --> 00:48:03,710

thanks Sean I have some trepidation

1293

00:48:06,940 --> 00:48:05,270

giving this talk because I'm not a

1294

00:48:08,920 --> 00:48:06,950

member of the links team or an x-ray

1295

00:48:10,450 --> 00:48:08,930

astronomer but we thought was important

1296

00:48:14,670 --> 00:48:10,460

enough that they'd be represented here

1297

00:48:16,960 --> 00:48:14,680

so that we make this presentation so the

1298

00:48:19,030 --> 00:48:16,970

main thing I wanted to get to is that

1299

00:48:21,220 --> 00:48:19,040

links is the next-generation x-ray

1300

00:48:22,870 --> 00:48:21,230

general-purpose Observatory following

1301

00:48:25,780 --> 00:48:22,880

the Chandra Observatory that was

1302

00:48:27,190 --> 00:48:25,790

launched in 1999 unlike the missions

1303

00:48:30,160 --> 00:48:27,200

we've just talked about it's not going

1304

00:48:32,290 --> 00:48:30,170

to be able to assess bio signatures on

1305

00:48:33,579 --> 00:48:32,300

exoplanets because planets don't really

1306

00:48:35,770 --> 00:48:33,589

emit in x-rays

1307

00:48:37,810 --> 00:48:35,780

however the environments of planets can

1308

00:48:39,609 --> 00:48:37,820

be very strongly affected by x-rays and

1309

00:48:41,560 --> 00:48:39,619

other forms of high-energy radiation and

1310

00:48:43,300 --> 00:48:41,570

so that's why we wanted to make sure you

1311

00:48:44,950 --> 00:48:43,310

knew about at this meeting this mission

1312

00:48:49,030 --> 00:48:44,960

could very build be the one that gets

1313

00:48:50,650 --> 00:48:49,040

selected by the decayed 'el so the ways

1314

00:48:53,349 --> 00:48:50,660

that are heliophysics colleagues know

1315

00:48:55,329 --> 00:48:53,359

that exoplanets get affected by their

1316

00:48:57,820 --> 00:48:55,339

high-energy environment or shown here

1317

00:48:59,620 --> 00:48:57,830

there's the photons from their host star

1318

00:49:01,630 --> 00:48:59,630

there's energetic particles and stellar

1319

00:49:03,730 --> 00:49:01,640

winds that are flowing by you know at

1320

00:49:06,160 --> 00:49:03,740

very high speeds and which have very hot

1321

00:49:08,800 --> 00:49:06,170

gas temperatures so these are going to

1322

00:49:10,900 --> 00:49:08,810

affect what happens to the exoplanet and

1323

00:49:11,950 --> 00:49:10,910

so the four ways that that can be a case

1324

00:49:13,990 --> 00:49:11,960

is that of course we have our own

1325

00:49:16,030 --> 00:49:14,000

stratosphere which is the structure of

1326

00:49:17,770 --> 00:49:16,040

which is determined by the input UV

1327

00:49:19,420 --> 00:49:17,780

radiation to the earth

1328

00:49:21,339 --> 00:49:19,430

this spectrum of input high-energy

1329

00:49:23,010 --> 00:49:21,349

radiation totally effects the

1330

00:49:25,570 --> 00:49:23,020

photochemistry in the upper atmosphere

1331

00:49:28,060 --> 00:49:25,580

and whether or not you have Hayes's form

1332

00:49:30,400 --> 00:49:28,070

that causes transparency to be affected

1333

00:49:32,170 --> 00:49:30,410

so that will affect what we can do with

1334

00:49:34,450 --> 00:49:32,180

our future missions the atmosphere

1335

00:49:36,609 --> 00:49:34,460

erosion and escape is driven in large

1336

00:49:38,290 --> 00:49:36,619

part by these high-energy processes and

1337

00:49:40,210 --> 00:49:38,300

this instability of the atmosphere

1338

00:49:42,910 --> 00:49:40,220

like for example what it's been seen

1339

00:49:44,800 --> 00:49:42,920

with maven and in the case of Mars's

1340

00:49:47,320 --> 00:49:44,810

atmosphere erosion and for the

1341

00:49:49,690 --> 00:49:47,330

biologists this high-energy environment

1342

00:49:51,730 --> 00:49:49,700

is either a good or a bad force for

1343

00:49:53,260 --> 00:49:51,740

forcing biochemical evolution so we

1344

00:49:55,840 --> 00:49:53,270

should really care for habitability

1345

00:49:58,330 --> 00:49:55,850

what's happening in our exoplanet host

1346

00:50:00,790 --> 00:49:58,340

star systems so links will be a leap in

1347

00:50:02,230 --> 00:50:00,800

sensitivity over Chandra Bob because

1348

00:50:04,180 --> 00:50:02,240

it's going to have 50 times the

1349

00:50:06,340 --> 00:50:04,190

effective area which means the optics

1350

00:50:08,770 --> 00:50:06,350

that are shown there on the in center of

1351

00:50:11,260 --> 00:50:08,780

the yellow circle are much more

1352

00:50:13,420 --> 00:50:11,270

concentrated than they were in the case

1353

00:50:16,360 --> 00:50:13,430

of Chandra and it'll have a specific

1354

00:50:18,730 --> 00:50:16,370

instrument set that's advanced as well

1355

00:50:21,720 --> 00:50:18,740

so here shows the Chandra mirrors these

1356

00:50:25,840 --> 00:50:21,730

nested cylinders on the upper left and

1357

00:50:28,300 --> 00:50:25,850

for 1,500 kilograms of mirror mass they

1358

00:50:30,460 --> 00:50:28,310

were only able to get a t-square of

1359

00:50:32,560 --> 00:50:30,470

sorry 0.08 meters squared of collecting

1360

00:50:34,240 --> 00:50:32,570

area links will have a larger outer

1361

00:50:35,560 --> 00:50:34,250

diameter for its primary but but you're

1362

00:50:37,600 --> 00:50:35,570

using these densely packed mirror

1363

00:50:39,970 --> 00:50:37,610

elements you'll be able to achieve much

1364

00:50:42,460 --> 00:50:39,980

larger effective collecting area with a

1365

00:50:43,750 --> 00:50:42,470

smaller mass it will have these three

1366

00:50:45,430 --> 00:50:43,760

instruments which I don't have time to

1367

00:50:47,470 --> 00:50:45,440

go into the grating spectrometer is

1368

00:50:49,810 --> 00:50:47,480

particularly useful for the applications

1369

00:50:52,630 --> 00:50:49,820

we're talking about here and so there

1370

00:50:53,980 --> 00:50:52,640

are really three areas where links could

1371

00:50:57,820 --> 00:50:53,990

be able to build on with Chandra and

1372

00:50:59,620 --> 00:50:57,830

xmm-newton Athena mission I would be

1373

00:51:01,570 --> 00:50:59,630

able to do to help exoplanet

1374

00:51:03,490 --> 00:51:01,580

habitability the first is characterizing

1375

00:51:06,340 --> 00:51:03,500

the spectrum of high energies that are

1376
00:51:10,120 --> 00:51:06,350
incident on our exoplanets and so here

1377
00:51:13,000 --> 00:51:10,130
is a plot of emergent radiation this is

1378
00:51:15,340 --> 00:51:13,010
a model from a store type star going

1379
00:51:17,140 --> 00:51:15,350
from one angstrom out to a thousand

1380
00:51:19,090 --> 00:51:17,150
angstrom so this covers the extreme

1381
00:51:21,040 --> 00:51:19,100
ultraviolet on the right and then sort

1382
00:51:22,630 --> 00:51:21,050
of the soft x-ray region the extreme

1383
00:51:25,780 --> 00:51:22,640
ultraviolet you can see all the lines

1384
00:51:28,060 --> 00:51:25,790
there from multiplied ni species that

1385
00:51:30,700 --> 00:51:28,070
those are the largest source of incoming

1386
00:51:33,460 --> 00:51:30,710
high energy flux that affects the upper

1387
00:51:35,380 --> 00:51:33,470
atmosphere and these issues of

1388
00:51:37,120 --> 00:51:35,390

habitability that we're talking about so

1389

00:51:38,800 --> 00:51:37,130

Lynx is going to not be able to observe

1390

00:51:41,620 --> 00:51:38,810

those directly but it'll be observing

1391

00:51:44,260 --> 00:51:41,630

the higher energy states of the same I

1392

00:51:46,180 --> 00:51:44,270

ins that are emitting in the extreme

1393

00:51:48,130 --> 00:51:46,190

ultraviolet so there'll be a direct way

1394

00:51:50,260 --> 00:51:48,140

to estimate what's happening in the

1395

00:51:51,640 --> 00:51:50,270

extreme ultraviolet from the Lynx

1396

00:51:53,380 --> 00:51:51,650

observations

1397

00:51:55,029 --> 00:51:53,390

and it will be able to do this four

1398

00:51:57,339 --> 00:51:55,039

stars that are inactive not just the

1399

00:51:59,829 --> 00:51:57,349

unusual flaring ones but regular stars

1400

00:52:01,779 --> 00:51:59,839

like the Sun as exoplanet hosts out to

1401

00:52:04,959 --> 00:52:01,789

ten parsecs or so the sensitivity of

1402

00:52:07,269 --> 00:52:04,969

links will be enabling that so then the

1403

00:52:09,640 --> 00:52:07,279

next area where the Lynx observations

1404

00:52:11,620 --> 00:52:09,650

could help is on stellar winds and the

1405

00:52:14,289 --> 00:52:11,630

time variable component we call the

1406

00:52:16,690 --> 00:52:14,299

coronal mass ejections so winds are very

1407

00:52:18,989 --> 00:52:16,700

hard to observe around other stars we

1408

00:52:21,279 --> 00:52:18,999

can't put a particle detector in the

1409

00:52:23,200 --> 00:52:21,289

heliosphere of another star and get back

1410

00:52:26,410 --> 00:52:23,210

measurements of the particle flux is

1411

00:52:28,539 --> 00:52:26,420

there but what we can do is take on very

1412

00:52:30,519 --> 00:52:28,549

highly ionized species like oxygen 7

1413

00:52:31,660 --> 00:52:30,529

here and as it flows out from the star

1414

00:52:33,579 --> 00:52:31,670

it's going to hit the interstellar

1415

00:52:37,089 --> 00:52:33,589

medium the gas between the stars and

1416

00:52:39,519 --> 00:52:37,099

it'll become a charge exchange with a

1417

00:52:41,410 --> 00:52:39,529

proton out there and then it'll be in an

1418

00:52:44,109 --> 00:52:41,420

excited state which will then decay and

1419

00:52:46,569 --> 00:52:44,119

produce x-ray emission so here's a model

1420

00:52:49,660 --> 00:52:46,579

that jeremy calculated back almost 20

1421

00:52:52,719 --> 00:52:49,670

years ago now showing how the radial

1422

00:52:55,660 --> 00:52:52,729

extent of a solar wind will produce this

1423

00:52:57,430 --> 00:52:55,670

charge exchange excited emission out to

1424

00:52:59,920 --> 00:52:57,440

large distances throughout the entire

1425

00:53:01,420 --> 00:52:59,930

sto sphere the bubble that the solar

1426

00:53:03,489 --> 00:53:01,430

wind creates in the interstellar medium

1427

00:53:07,150 --> 00:53:03,499

we don't have the sensitivity to observe

1428

00:53:08,620 --> 00:53:07,160

this with current observatories but

1429

00:53:10,959 --> 00:53:08,630

we'll be actually able to see the

1430

00:53:14,620 --> 00:53:10,969

extended a cloud of x-ray emission

1431

00:53:16,150 --> 00:53:14,630

around up 20 nearby stars here iam by

1432

00:53:17,559 --> 00:53:16,160

measuring the brightness and the size of

1433

00:53:19,569 --> 00:53:17,569

this and making some assumptions about

1434

00:53:21,309 --> 00:53:19,579

the interstellar medium density we'll be

1435

00:53:23,650 --> 00:53:21,319

able to infer the strength of the

1436

00:53:25,390 --> 00:53:23,660

stellar wind and be able hopefully also

1437

00:53:27,430 --> 00:53:25,400

to get some radial velocity measurements

1438

00:53:28,509 --> 00:53:27,440

so at least 20 stars will have direct

1439

00:53:30,880 --> 00:53:28,519

measurements of the particle

1440

00:53:33,219 --> 00:53:30,890

environments that the exoplanets they

1441

00:53:35,589 --> 00:53:33,229

are experiencing so part of that

1442

00:53:37,569 --> 00:53:35,599

environment is the variability in the

1443

00:53:40,319 --> 00:53:37,579

winds these coronal mass ejections seen

1444

00:53:42,069 --> 00:53:40,329

here in the Solar Dynamics Observatory

1445

00:53:44,229 --> 00:53:42,079

observations as these are the kind of

1446

00:53:45,430 --> 00:53:44,239

things that only happen occasionally but

1447

00:53:47,650 --> 00:53:45,440

when they do they have a really large

1448

00:53:50,279 --> 00:53:47,660

effect on atmospheric stripping again in

1449

00:53:53,499 --> 00:53:50,289

the Maven example so here's a Chandra

1450

00:53:56,620 --> 00:53:53,509

Observatory x-ray spectrum spectrum time

1451
00:53:59,229 --> 00:53:56,630
series of these flares and mass ejection

1452
00:54:00,579 --> 00:53:59,239
events going from left to right this is

1453
00:54:02,769 --> 00:54:00,589
something we can see now and very

1454
00:54:04,959 --> 00:54:02,779
flaring and active stars but we can't

1455
00:54:05,240 --> 00:54:04,969
really measure in stars that are more

1456
00:54:07,220 --> 00:54:05,250
like

1457
00:54:10,270 --> 00:54:07,230
son acquiescent 1 so links could make

1458
00:54:12,740 --> 00:54:10,280
this measurement for for typical stars

1459
00:54:14,840 --> 00:54:12,750
along with radial velocity measurements

1460
00:54:17,660 --> 00:54:14,850
of the strength of the flow and this

1461
00:54:18,920 --> 00:54:17,670
would have a large impact the modelers

1462
00:54:21,170 --> 00:54:18,930
who are trying to see how fast

1463
00:54:24,050 --> 00:54:21,180

atmosphere is arose so the last thing is

1464

00:54:27,140 --> 00:54:24,060

just like JWST and the origins mission

1465

00:54:30,170 --> 00:54:27,150

you can do spectroscopy of an exoplanet

1466

00:54:32,330 --> 00:54:30,180

in transit in x-rays so this is the only

1467

00:54:36,620 --> 00:54:32,340

detection that's taken place to date of

1468

00:54:38,570 --> 00:54:36,630

a hot Jupiter HD 189 733 that sorry

1469

00:54:40,220 --> 00:54:38,580

that's incorrectly labeled there with

1470

00:54:42,320 --> 00:54:40,230

the Chandra Observatory you can see it's

1471

00:54:43,640 --> 00:54:42,330

a very marginal detection fortunately we

1472

00:54:46,070 --> 00:54:43,650

know the time of the transit well from

1473

00:54:48,500 --> 00:54:46,080

other techniques but if we can do this

1474

00:54:50,120 --> 00:54:48,510

in the x-ray this is a simulated

1475

00:54:52,010 --> 00:54:50,130

observation with links seen you can see

1476

00:54:54,170 --> 00:54:52,020

the planet moving across the star

1477

00:54:55,550 --> 00:54:54,180

there's a solid core of the planet and

1478

00:54:57,440 --> 00:54:55,560

if there was an extended escaping

1479

00:54:59,420 --> 00:54:57,450

atmosphere that's what will give us the

1480

00:55:01,400 --> 00:54:59,430

leverage to see the absorption feature

1481

00:55:03,470 --> 00:55:01,410

there and then do spectroscopy of it so

1482

00:55:05,390 --> 00:55:03,480

the composition of the atmosphere could

1483

00:55:07,790 --> 00:55:05,400

be inferred for this certainly for hot

1484

00:55:10,160 --> 00:55:07,800

Jupiters around solar-type stars as in

1485

00:55:12,020 --> 00:55:10,170

this example but potentially also for

1486

00:55:13,970 --> 00:55:12,030

earth-size planets around those small M

1487

00:55:16,880 --> 00:55:13,980

stars that we hear our other transit

1488

00:55:19,700 --> 00:55:16,890

missions talk about so in summary you

1489

00:55:21,860 --> 00:55:19,710

know links will assess the energetic

1490

00:55:23,990 --> 00:55:21,870

extreme ultraviolet and x-ray fluxes of

1491

00:55:26,510 --> 00:55:24,000

inactive stars reaching many times

1492

00:55:28,760 --> 00:55:26,520

farther than other facilities and this

1493

00:55:30,980 --> 00:55:28,770

dark energy of the of the winds of the

1494

00:55:32,780 --> 00:55:30,990

stars and kernel mass ejections will

1495

00:55:35,510 --> 00:55:32,790

inform us at what kind of environment

1496

00:55:37,880 --> 00:55:35,520

may have taken place around the

1497

00:55:39,290 --> 00:55:37,890

exoplanets that you know Lua or hab X or

1498

00:55:41,780 --> 00:55:39,300

some future mission would be able to see

1499

00:55:44,030 --> 00:55:41,790

spectra of the composition information

1500

00:55:46,100 --> 00:55:44,040

is potentially there and the main thing

1501

00:55:48,500 --> 00:55:46,110

that main Able's links to do this is it

1502

00:55:50,930 --> 00:55:48,510

has the very high spatial resolution of

1503

00:55:52,820 --> 00:55:50,940

only half an arc second relative to the

1504

00:55:54,410 --> 00:55:52,830

Chandra Observatory and even the start

1505

00:56:04,680 --> 00:55:54,420

relative to the XM m and even the Athena

1506

00:56:12,099 --> 00:56:08,170

okay I would like to invite up doctors

1507

00:56:13,240 --> 00:56:12,109

Meadows Stevenson County and Arnie for a

1508

00:56:14,830 --> 00:56:13,250

panel discussion so if you have

1509

00:56:16,690 --> 00:56:14,840

questions about anything you just saw

1510

00:56:20,170 --> 00:56:16,700

from these folks please head up to the

1511

00:56:21,820 --> 00:56:20,180

microphones and ask your question while

1512

00:56:24,670 --> 00:56:21,830

you're moving there and folks are moving

1513

00:56:26,230 --> 00:56:24,680

up onto the stage to the table I will

1514

00:56:27,280 --> 00:56:26,240

make two points one reminder of

1515

00:56:27,700 --> 00:56:27,290

something Carl said at the start of the

1516

00:56:29,320 --> 00:56:27,710

session

1517

00:56:31,150 --> 00:56:29,330

none of these missions are happening for

1518

00:56:32,980 --> 00:56:31,160

sure they are all constant missions that

1519

00:56:34,690 --> 00:56:32,990

are being submitted to the decadal

1520

00:56:37,240 --> 00:56:34,700

survey the astrophysics decadal survey

1521

00:56:39,490 --> 00:56:37,250

for consideration except for Jay divas

1522

00:56:42,390 --> 00:56:39,500

team which has gone through the Cadle

1523

00:56:45,910 --> 00:56:42,400

survey thank you something we don't know

1524

00:56:49,500 --> 00:56:45,920

thank you and to all of them including

1525

00:56:51,790 --> 00:56:49,510

JWST this time do a lot of astrophysics

1526
00:56:52,930 --> 00:56:51,800
related to how habitable environments

1527
00:56:54,550 --> 00:56:52,940
could have formed in our universe in the

1528
00:56:56,349 --> 00:56:54,560
first place and we asked all all of

1529
00:56:59,109 --> 00:56:56,359
these folks to talk about the exoplanet

1530
00:57:01,030 --> 00:56:59,119
habitability and bioenergy bio signature

1531
00:57:03,550 --> 00:57:01,040
case specifically but it's that's not

1532
00:57:06,250 --> 00:57:03,560
the only astrobiology they do okay I'm

1533
00:57:08,710 --> 00:57:06,260
gonna start with dr. Mary gita I was

1534
00:57:10,480 --> 00:57:08,720
wondering if you guys could comment on

1535
00:57:13,930 --> 00:57:10,490
the other missions that are out there so

1536
00:57:16,930 --> 00:57:13,940
Plateau and Ariel from ISA and also the

1537
00:57:21,280 --> 00:57:16,940
contributions that TMT if it gets built

1538
00:57:22,450 --> 00:57:21,290

an ELT will make to the search maybe

1539

00:57:26,079 --> 00:57:22,460

let's go through the who wants to take

1540

00:57:27,880 --> 00:57:26,089

plate oh I can make play-doh or plot oh

1541

00:57:28,930 --> 00:57:27,890

I know I've never gotten a straight

1542

00:57:32,020 --> 00:57:28,940

answer and how I'm supposed to pronounce

1543

00:57:37,420 --> 00:57:32,030

it so this is a fantastic mission which

1544

00:57:40,800 --> 00:57:37,430

is a ISA m4 as I think m4 mission and

1545

00:57:44,250 --> 00:57:40,810

it's you can think of it something like

1546

00:57:47,320 --> 00:57:44,260

Hubble on steroids so it has a 500

1547

00:57:50,140 --> 00:57:47,330

square degree field of view it has

1548

00:57:52,810 --> 00:57:50,150

something like 32 cameras and they're

1549

00:57:55,329 --> 00:57:52,820

gonna what look at their in within this

1550

00:57:56,770 --> 00:57:55,339

500 square degree field of view it's

1551
00:57:59,770 --> 00:57:56,780
going to look at so that's roughly five

1552
00:58:01,210 --> 00:57:59,780
times Kepler it's gonna look the set

1553
00:58:03,099 --> 00:58:01,220
they'll have several cameras pointing at

1554
00:58:05,020 --> 00:58:03,109
each section and there'll be a central I

1555
00:58:07,990 --> 00:58:05,030
think 200 square degrees where there's

1556
00:58:09,790 --> 00:58:08,000
32 cameras it has a somewhat different

1557
00:58:11,500 --> 00:58:09,800
strategy as Kepler at least the current

1558
00:58:12,300 --> 00:58:11,510
plan scratch strategy it's still in flux

1559
00:58:15,060 --> 00:58:12,310
as I understand

1560
00:58:16,710 --> 00:58:15,070
it it will look at two fields for two to

1561
00:58:18,690 --> 00:58:16,720
three years each

1562
00:58:21,390 --> 00:58:18,700
so it'll that's sort of almost the

1563
00:58:23,070 --> 00:58:21,400

duration of the Kepler large field and

1564

00:58:25,470 --> 00:58:23,080

so it will be sensitive potentially

1565

00:58:26,910 --> 00:58:25,480

habitable planets earth-like planets

1566

00:58:29,580 --> 00:58:26,920

orbiting sun-like stars so it could

1567

00:58:31,800 --> 00:58:29,590

improve our estimate of a to earth but

1568

00:58:34,170 --> 00:58:31,810

it also do a steppin stare for along the

1569

00:58:35,820 --> 00:58:34,180

ecliptic if I don't remember how many is

1570

00:58:37,890 --> 00:58:35,830

something like a dozen fields and so

1571

00:58:41,280 --> 00:58:37,900

it'll find a lot of really bright stars

1572

00:58:43,080 --> 00:58:41,290

I think but plateaus real contribution

1573

00:58:44,820 --> 00:58:43,090

that's going to be not only finding

1574

00:58:47,220 --> 00:58:44,830

transiting planets around bright stars

1575

00:58:48,930 --> 00:58:47,230

but it'll actually be able to do Astro

1576

00:58:50,880 --> 00:58:48,940

seismology at a very large number of

1577

00:58:52,830 --> 00:58:50,890

stars so we can be able to do things

1578

00:58:54,450 --> 00:58:52,840

like ask about the frequency of planets

1579

00:58:56,730 --> 00:58:54,460

as a function of not only the host

1580

00:58:57,990 --> 00:58:56,740

spectral type but also the age and I

1581

00:59:00,210 --> 00:58:58,000

think that's one of the most important

1582

00:59:03,030 --> 00:59:00,220

things so when someone do you want to

1583

00:59:04,380 --> 00:59:03,040

take Arielle so oil is also an Easton

1584

00:59:08,460 --> 00:59:04,390

mission is planning to launch I think in

1585

00:59:11,880 --> 00:59:08,470

2027 or 2028 it is a roughly one meter

1586

00:59:13,920 --> 00:59:11,890

diameter Mir but 1.1 by 0.7 it's an oval

1587

00:59:16,170 --> 00:59:13,930

mirror and it'll do primarily

1588

00:59:18,630 --> 00:59:16,180

transmission and mission spectroscopy so

1589

00:59:20,190 --> 00:59:18,640

this will be operating typically in the

1590

00:59:22,170 --> 00:59:20,200

near and mid-infrared it has an

1591

00:59:24,000 --> 00:59:22,180

instrument for two to seven microns and

1592

00:59:26,370 --> 00:59:24,010

also a second guiding instrument with

1593

00:59:28,980 --> 00:59:26,380

some spectroscopy capabilities in these

1594

00:59:31,230 --> 00:59:28,990

sort of 0.5 to 2 micron range its

1595

00:59:34,370 --> 00:59:31,240

primary science focus will be more

1596

00:59:37,440 --> 00:59:34,380

survey based rather than looking at a

1597

00:59:39,540 --> 00:59:37,450

small number of exoplanets because the

1598

00:59:41,640 --> 00:59:39,550

overlapping wavelength range with James

1599

00:59:43,230 --> 00:59:41,650

Webb it won't be able to do the in-depth

1600

00:59:45,300 --> 00:59:43,240

atmosphere characterization but if you

1601
00:59:47,130 --> 00:59:45,310
think about how much time it takes to

1602
00:59:49,170 --> 00:59:47,140
build up a statistically significant

1603
00:59:51,420 --> 00:59:49,180
sample size for many of these for sample

1604
00:59:53,100 --> 00:59:51,430
hot Jupiters and warm Neptune's it will

1605
00:59:55,200 --> 00:59:53,110
be able to look at hundreds of these

1606
00:59:57,570 --> 00:59:55,210
planets perhaps doing phase curve

1607
00:59:59,940 --> 00:59:57,580
observations certainly the transits and

1608
01:00:01,380 --> 00:59:59,950
eclipses and build up a broader

1609
01:00:03,330 --> 01:00:01,390
understanding of these planets this is a

1610
01:00:05,760 --> 01:00:03,340
really good opportunity to do exoplanet

1611
01:00:10,170 --> 01:00:05,770
plug atmospheric studies with the

1612
01:00:11,910 --> 01:00:10,180
planets and so for the ground-based yes

1613
01:00:12,570 --> 01:00:11,920

there are three telescopes that are

1614

01:00:17,550 --> 01:00:12,580

being built

1615

01:00:20,580 --> 01:00:17,560

TMT GMT and ELT two to US and European

1616

01:00:22,400 --> 01:00:20,590

telescopes as well and they will have 30

1617

01:00:24,270 --> 01:00:22,410

to 40 metre apertures on the ground

1618

01:00:25,950 --> 01:00:24,280

their challenge is

1619

01:00:27,390 --> 01:00:25,960

looking through an earth-like habitable

1620

01:00:28,980 --> 01:00:27,400

atmosphere to try and study in

1621

01:00:30,510 --> 01:00:28,990

earth-like how to atmosphere elsewhere

1622

01:00:32,040 --> 01:00:30,520

but they've come out with a really

1623

01:00:34,740 --> 01:00:32,050

interesting technique called template

1624

01:00:37,470 --> 01:00:34,750

matching where they use ultra-high

1625

01:00:39,780 --> 01:00:37,480

resolution spectroscopy and rely on the

1626
01:00:41,700 --> 01:00:39,790
motion of the planet around its star as

1627
01:00:43,350 --> 01:00:41,710
she shift those spectral lines backwards

1628
01:00:44,940 --> 01:00:43,360
and forwards and if you know the orbital

1629
01:00:47,190 --> 01:00:44,950
period you can actually look for

1630
01:00:48,480 --> 01:00:47,200
something shifting in the data that is

1631
01:00:50,130 --> 01:00:48,490
not the Earth's atmosphere the Earth's

1632
01:00:52,590 --> 01:00:50,140
atmosphere thankfully stays very steady

1633
01:00:54,060 --> 01:00:52,600
and so these lines will move

1634
01:00:56,280 --> 01:00:54,070
backwards and forwards within that so

1635
01:00:58,710 --> 01:00:56,290
there is the possibility in the next

1636
01:01:00,780 --> 01:00:58,720
three to five years potentially to go

1637
01:01:02,940 --> 01:01:00,790
for oxygen from the ground using this

1638
01:01:04,500 --> 01:01:02,950

particular technique but we've yet to

1639

01:01:06,480 --> 01:01:04,510

see how successful that's going to be

1640

01:01:08,430 --> 01:01:06,490

you know even with that shift whether or

1641

01:01:10,350 --> 01:01:08,440

not we're able to disentangle that from

1642

01:01:12,300 --> 01:01:10,360

the Earth's atmosphere but that's

1643

01:01:13,320 --> 01:01:12,310

certainly high on the list for those

1644

01:01:15,060 --> 01:01:13,330

telescopes and some of the first

1645

01:01:17,220 --> 01:01:15,070

generation instruments are going to be

1646

01:01:20,340 --> 01:01:17,230

looking for that at the moment the VLT

1647

01:01:21,870 --> 01:01:20,350

the Very Large Telescope which is the

1648

01:01:24,900 --> 01:01:21,880

precursor of the ELT the extremely large

1649

01:01:26,160 --> 01:01:24,910

telescope so the VLT they're also

1650

01:01:28,800 --> 01:01:26,170

looking at potentially coupling

1651

01:01:30,540 --> 01:01:28,810

instruments together a sort of a

1652

01:01:33,000 --> 01:01:30,550

starlight suppression system and a very

1653

01:01:34,830 --> 01:01:33,010

high resolution spectrometer to be able

1654

01:01:37,860 --> 01:01:34,840

to go after this in the very short term

1655

01:01:41,070 --> 01:01:37,870

for Proxima Centauri B which is a very

1656

01:01:42,600 --> 01:01:41,080

good target for that so possibly even in

1657

01:01:44,370 --> 01:01:42,610

sort of the next three to five years we

1658

01:01:46,410 --> 01:01:44,380

might have actually attempt to do that

1659

01:01:47,910 --> 01:01:46,420

so the ground will race JWST actually

1660

01:01:50,400 --> 01:01:47,920

for the first detection of an atmosphere

1661

01:01:52,800 --> 01:01:50,410

around a terrestrial type planet I will

1662

01:01:54,360 --> 01:01:52,810

say that for a handful of targets I

1663

01:01:56,430 --> 01:01:54,370

think it's it's still under somewhat of

1664

01:01:58,500 --> 01:01:56,440

a debate exactly how many and it depends

1665

01:02:00,150 --> 01:01:58,510

on what the ultimate performance of

1666

01:02:02,580 --> 01:02:00,160

these very large telescopes are going to

1667

01:02:05,550 --> 01:02:02,590

be it may be able to do direct imaging

1668

01:02:07,770 --> 01:02:05,560

of earth-like planets around em nearby M

1669

01:02:09,900 --> 01:02:07,780

stars a handful of nearby M stars and

1670

01:02:12,560 --> 01:02:09,910

also maybe we'd be able to do mid

1671

01:02:16,200 --> 01:02:12,570

infrared observations I think there's a

1672

01:02:18,300 --> 01:02:16,210

tellement called Medus on ELT that could

1673

01:02:20,880 --> 01:02:18,310

actually do thermal observations and for

1674

01:02:23,370 --> 01:02:20,890

even a very small number of planets and

1675

01:02:26,640 --> 01:02:23,380

may be possible to do both optical and

1676

01:02:28,680 --> 01:02:26,650

mid infrared imaging to get both the

1677

01:02:30,390 --> 01:02:28,690

spectra but also the sizes and albedo

1678

01:02:33,450 --> 01:02:30,400

and radii which would be

1679

01:02:34,980 --> 01:02:33,460

quite impressive one other comment so

1680

01:02:36,240 --> 01:02:34,990

there's the there's the template

1681

01:02:37,920 --> 01:02:36,250

matching technique but there's also just

1682

01:02:39,120 --> 01:02:37,930

transmission spectroscopy which will

1683

01:02:40,080 --> 01:02:39,130

also be attempted and I believe there's

1684

01:02:43,050 --> 01:02:40,090

gonna be a talk on that in the

1685

01:02:44,370 --> 01:02:43,060

characterizing exoplanets session so but

1686

01:02:46,410 --> 01:02:44,380

the but the thing you should take away

1687

01:02:48,390 --> 01:02:46,420

from this too is except for the direct

1688

01:02:49,710 --> 01:02:48,400

imaging we will again be studying these

1689

01:02:52,410 --> 01:02:49,720

M dwarf planets which have this

1690

01:02:53,460 --> 01:02:52,420

interesting childhood and and that's and

1691

01:02:54,690 --> 01:02:53,470

that's fun and interesting from a

1692

01:02:56,220 --> 01:02:54,700

terrestrial exoplanet evolution

1693

01:02:58,410 --> 01:02:56,230

standpoint but if we really want to go

1694

01:03:00,810 --> 01:02:58,420

after the sun-like stars things like you

1695

01:03:03,210 --> 01:03:00,820

know the star that we orbit then we are

1696

01:03:06,360 --> 01:03:03,220

waiting for the space-based direct

1697

01:03:09,300 --> 01:03:06,370

imaging missions to do that okay next

1698

01:03:12,600 --> 01:03:09,310

question here hi Ben Pierce McMaster

1699

01:03:14,940 --> 01:03:12,610

University so after listening to dr.

1700

01:03:17,130 --> 01:03:14,950

meadows and dr. Arnie's talks it sounds

1701

01:03:20,100 --> 01:03:17,140

to me like the remote detection of

1702

01:03:22,950 --> 01:03:20,110

oxygen in a planetary atmosphere with

1703

01:03:24,900 --> 01:03:22,960

Jeddah vesti and loop are is kind of

1704

01:03:27,930 --> 01:03:24,910

grim at least with respect to Trappist

1705

01:03:29,640 --> 01:03:27,940

one-e-and with low atmospheric levels of

1706

01:03:31,470 --> 01:03:29,650

oxygen so can you comment more on this

1707

01:03:33,330 --> 01:03:31,480

you know is there potential to fine

1708

01:03:35,160 --> 01:03:33,340

oxygen and and what are the limits what

1709

01:03:37,170 --> 01:03:35,170

does the planet have to have for for

1710

01:03:40,260 --> 01:03:37,180

oxygen levels in order for you to detect

1711

01:03:42,870 --> 01:03:40,270

it well I don't think it's criminal for

1712

01:03:45,780 --> 01:03:42,880

levar I think Earth's history tells us

1713

01:03:47,070 --> 01:03:45,790

that maybe earth-like planets with large

1714

01:03:48,540 --> 01:03:47,080

amounts of oxygen might not be too

1715

01:03:50,760 --> 01:03:48,550

common if we just think about the

1716

01:03:52,800 --> 01:03:50,770

history of our planet but that isn't the

1717

01:03:54,270 --> 01:03:52,810

be-all-end-all of bio signatures like we

1718

01:03:55,560 --> 01:03:54,280

frequently start our conversations with

1719

01:03:57,060 --> 01:03:55,570

oxygen just because it's such an

1720

01:03:59,580 --> 01:03:57,070

important byte signature for Earth and

1721

01:04:00,960 --> 01:03:59,590

modern day earth but there are other bio

1722

01:04:02,220 --> 01:04:00,970

signatures that we need to be thinking

1723

01:04:04,320 --> 01:04:02,230

about because they have been strongly

1724

01:04:06,420 --> 01:04:04,330

detectable for a large fraction of our

1725

01:04:07,800 --> 01:04:06,430

planets history like methane in the

1726

01:04:09,810 --> 01:04:07,810

context of an atmosphere a lot of co2

1727

01:04:12,510 --> 01:04:09,820

would implies high source fluxes of that

1728

01:04:14,220 --> 01:04:12,520

methane that can point to life ozone is

1729

01:04:15,990 --> 01:04:14,230

a way to indirectly infer the presence

1730

01:04:17,850 --> 01:04:16,000

of oxygen even if you can't detect the

1731

01:04:19,380 --> 01:04:17,860

oxygen itself if you can detect that

1732

01:04:20,910 --> 01:04:19,390

ozone feature you know the oxygen is

1733

01:04:23,010 --> 01:04:20,920

there it's just not you know it's just

1734

01:04:24,690 --> 01:04:23,020

not especially expressing itself so I

1735

01:04:28,110 --> 01:04:24,700

knew that the picture is not quite so

1736

01:04:29,859 --> 01:04:28,120

grim as it might have come across like I

1737

01:04:31,569 --> 01:04:29,869

I'm actually pretty optimistic

1738

01:04:33,699 --> 01:04:31,579

about lavars prospects for biased

1739

01:04:35,859 --> 01:04:33,709

nurtured detection yeah so I I'm

1740

01:04:37,929 --> 01:04:35,869

surprised that you got that from from

1741

01:04:39,370 --> 01:04:37,939

will give our presentation and if you

1742

01:04:41,829 --> 01:04:39,380

thought mad that's why I'm sure you

1743

01:04:44,380 --> 01:04:41,839

think Havoc's is completely dead not

1744

01:04:46,420 --> 01:04:44,390

just grim but actually have X was

1745

01:04:48,309 --> 01:04:46,430

designed to be able to detect the oxygen

1746

01:04:49,989 --> 01:04:48,319

band at point I mean it one of the

1747

01:04:51,880 --> 01:04:49,999

requirements is that it is able to

1748

01:04:55,269 --> 01:04:51,890

detect at signal-to-noise 10 and

1749

01:04:58,059 --> 01:04:55,279

resolution of 140 the oxygen the o2 band

1750

01:05:00,819 --> 01:04:58,069

at 0.76 microns is that right

1751

01:05:03,309 --> 01:05:00,829

and of course ozone is is much easier to

1752

01:05:05,920 --> 01:05:03,319

detect so you could detect ozone and

1753

01:05:07,599 --> 01:05:05,930

even lower levels and as Giada and Giada

1754

01:05:09,729 --> 01:05:07,609

said and maybe this point wasn't I

1755

01:05:11,589 --> 01:05:09,739

didn't make this very clearly we

1756

01:05:13,959 --> 01:05:11,599

actually think that we can detect a lot

1757

01:05:16,209 --> 01:05:13,969

of the bio alternative bio signatures

1758

01:05:18,519 --> 01:05:16,219

that Giada talked about over the course

1759

01:05:21,370 --> 01:05:18,529

of the earth even with Havoc's of course

1760

01:05:23,499 --> 01:05:21,380

it's for much smaller numbers of targets

1761

01:05:25,929 --> 01:05:23,509

but nevertheless we can still do it for

1762

01:05:27,459 --> 01:05:25,939

a significant number significant a large

1763

01:05:29,199 --> 01:05:27,469

enough sample that we can say put an

1764

01:05:31,479 --> 01:05:29,209

interesting upper limit so I don't think

1765

01:05:33,519 --> 01:05:31,489

it's grim at all I think with the only

1766

01:05:36,669 --> 01:05:33,529

place where it's slightly it's slightly

1767

01:05:37,929 --> 01:05:36,679

grim is maybe bio signatures with JWST

1768

01:05:40,390 --> 01:05:37,939

would you agree with that Vickie

1769

01:05:43,749 --> 01:05:40,400

absolutely so so I think these to you

1770

01:05:47,410 --> 01:05:43,759

the oxygen bio signature with JWST is

1771

01:05:48,789 --> 01:05:47,420

grim but we can detect very high levels

1772

01:05:50,199 --> 01:05:48,799

of oxygen from ocean laws pretty

1773

01:05:52,120 --> 01:05:50,209

straightforwardly so you may we may

1774

01:05:53,709 --> 01:05:52,130

ironically see oxygen on planets

1775

01:05:54,669 --> 01:05:53,719

orbiting M dwarfs but at such abundance

1776

01:05:56,140 --> 01:05:54,679

that it doesn't look like it's a

1777

01:05:58,539 --> 01:05:56,150

biosphere looks like it's a remnant lost

1778

01:06:00,130 --> 01:05:58,549

ocean so that's gonna happen but then we

1779

01:06:01,509 --> 01:06:00,140

also have the ground and and the ground

1780

01:06:02,829 --> 01:06:01,519

will go so in the near term in the next

1781

01:06:05,529 --> 01:06:02,839

five years the ground is going to go

1782

01:06:07,089 --> 01:06:05,539

after the oxygen as well so I don't

1783

01:06:09,640 --> 01:06:07,099

think it's grim in this landscape it's

1784

01:06:10,870 --> 01:06:09,650

just you know JWST has a certain and I

1785

01:06:13,449 --> 01:06:10,880

may have glossed over it in the summary

1786

01:06:15,699 --> 01:06:13,459

but jdbc is gonna be awesome for methane

1787

01:06:17,890 --> 01:06:15,709

even at current earth light fluxes and

1788

01:06:19,419 --> 01:06:17,900

so it can go after the methane the

1789

01:06:21,279 --> 01:06:19,429

ground could go after the o2 in the

1790

01:06:22,809 --> 01:06:21,289

short term and then we have these you

1791

01:06:24,489 --> 01:06:22,819

know potentially at the selection of a

1792

01:06:26,739 --> 01:06:24,499

far more capable any of these telescopes

1793

01:06:28,569 --> 01:06:26,749

are far more capable than what JWST will

1794

01:06:30,069 --> 01:06:28,579

be able to do and so there's this I

1795

01:06:31,589 --> 01:06:30,079

think a very bright future for oxygen

1796

01:06:33,550 --> 01:06:31,599

detection from one of these missions

1797

01:06:36,700 --> 01:06:33,560

thank you

1798

01:06:39,580 --> 01:06:36,710

Kevin your speak for origins on ozone or

1799

01:06:42,130 --> 01:06:39,590

oxygen right so Origin Space Telescope

1800

01:06:44,710 --> 01:06:42,140

won't have access directly to oxygen but

1801
01:06:46,750 --> 01:06:44,720
because ozone as the giada was

1802
01:06:49,240 --> 01:06:46,760
mentioning if presence of ozone

1803
01:06:50,380 --> 01:06:49,250
indicates the oxygen exists we'll be

1804
01:06:54,160 --> 01:06:50,390
able to detect that nine point eight

1805
01:06:55,600 --> 01:06:54,170
microns and I think with web with the

1806
01:06:57,340 --> 01:06:55,610
Miri instrument and will be challenging

1807
01:06:59,100 --> 01:06:57,350
to do but with origins if it goes

1808
01:07:02,080 --> 01:06:59,110
through with as designed then I think

1809
01:07:04,450 --> 01:07:02,090
zone will be after co2 the next easiest

1810
01:07:06,130 --> 01:07:04,460
molecule to detect any I believe just a

1811
01:07:08,470 --> 01:07:06,140
point of clarification I for trap for

1812
01:07:09,550 --> 01:07:08,480
the Trappist system it is a little bit

1813
01:07:10,740 --> 01:07:09,560

more grim for the direct imaging

1814

01:07:14,170 --> 01:07:10,750

missions is that correct

1815

01:07:15,490 --> 01:07:14,180

transition yeah it's it's I'm sorry for

1816

01:07:23,070 --> 01:07:15,500

the drugged imitate transiting for the

1817

01:07:27,280 --> 01:07:25,510

toxin we could do right and Proxima

1818

01:07:28,990 --> 01:07:27,290

sentient transit so direct imaging is

1819

01:07:31,030 --> 01:07:29,000

the best way to go and after that that

1820

01:07:34,120 --> 01:07:31,040

and the the ground-based template

1821

01:07:35,980 --> 01:07:34,130

matching there's your question yep okay

1822

01:07:38,020 --> 01:07:35,990

Carl I think you were next and then

1823

01:07:41,110 --> 01:07:38,030

we'll come to this other mic thanks i'm

1824

01:07:42,400 --> 01:07:41,120

karl pilkington stitute of science and i

1825

01:07:45,430 --> 01:07:42,410

don't have a question but i'd like to

1826
01:07:48,010 --> 01:07:45,440
make two related observations the first

1827
01:07:49,660 --> 01:07:48,020
is that we have just seen an update on

1828
01:07:52,000 --> 01:07:49,670
the planning for what is clearly a

1829
01:07:54,610 --> 01:07:52,010
century long or perhaps more than a

1830
01:07:58,120 --> 01:07:54,620
century long endeavor and it's worth

1831
01:08:00,280 --> 01:07:58,130
reflecting on how remarkable it is that

1832
01:08:03,160 --> 01:08:00,290
the federal government supports an

1833
01:08:06,070 --> 01:08:03,170
endeavor of this nature most federal

1834
01:08:08,740 --> 01:08:06,080
agencies do not work on century long

1835
01:08:11,470 --> 01:08:08,750
timescales in fact you're hard-pressed

1836
01:08:14,320 --> 01:08:11,480
to find a federal agency that works on a

1837
01:08:17,710 --> 01:08:14,330
time scale longer than oh let's say five

1838
01:08:20,140 --> 01:08:17,720

years occasionally ten the Veterans

1839

01:08:22,809 --> 01:08:20,150

Administration is one for obvious

1840

01:08:27,660 --> 01:08:22,819

reasons the EPA when it's working

1841

01:08:31,450 --> 01:08:27,670

properly is another but this concept of

1842

01:08:35,230 --> 01:08:31,460

the federal government supporting a a

1843

01:08:37,450 --> 01:08:35,240

century long endeavor to get information

1844

01:08:39,370 --> 01:08:37,460

about earth-like planets and and

1845

01:08:41,650 --> 01:08:39,380

potentially find life on a planet around

1846

01:08:44,650 --> 01:08:41,660

another star is just amazing and it

1847

01:08:45,160 --> 01:08:44,660

speaks I think to how compelling this

1848

01:08:49,590 --> 01:08:45,170

and

1849

01:08:51,880 --> 01:08:49,600

is it's compelling on the same level as

1850

01:08:54,970 --> 01:08:51,890

maintaining the habitability of our own

1851
01:08:57,820 --> 01:08:54,980
planet and supporting people who have

1852
01:09:01,030 --> 01:08:57,830
served this planet this country and and

1853
01:09:03,550 --> 01:09:01,040
in some cases at great great expense to

1854
01:09:07,680 --> 01:09:03,560
themselves so it's worth thinking about

1855
01:09:11,590 --> 01:09:07,690
that the other observation is how many

1856
01:09:14,680 --> 01:09:11,600
young people students other early career

1857
01:09:16,630 --> 01:09:14,690
researchers are here at this meeting I'm

1858
01:09:20,050 --> 01:09:16,640
seeing lots and lots of faces that I

1859
01:09:22,660 --> 01:09:20,060
have not seen at previous apps icons and

1860
01:09:24,729 --> 01:09:22,670
one of the great things about this field

1861
01:09:27,450 --> 01:09:24,739
in this community of course and I think

1862
01:09:31,030 --> 01:09:27,460
everybody in this room knows it is how

1863
01:09:32,979 --> 01:09:31,040

well it attracts the best young

1864

01:09:35,260 --> 01:09:32,989

researchers because we have these

1865

01:09:38,860 --> 01:09:35,270

profoundly important problems and

1866

01:09:39,999 --> 01:09:38,870

stimulating problems to work on the

1867

01:09:43,780 --> 01:09:40,009

relationship between these two

1868

01:09:46,090 --> 01:09:43,790

observations is is pretty clear it's a

1869

01:09:48,099 --> 01:09:46,100

really good thing that the second one is

1870

01:09:51,010 --> 01:09:48,109

true given that the first one is true

1871

01:09:54,760 --> 01:09:51,020

but it really is I think together these

1872

01:09:57,620 --> 01:09:54,770

are really the the glories of this field

1873

01:10:03,879 --> 01:10:01,359

[Applause]

1874

01:10:05,890 --> 01:10:03,889

those are two fantastic points I want to

1875

01:10:09,070 --> 01:10:05,900

I want to mention something about the

1876

01:10:12,129 --> 01:10:09,080

briefly sort of a debrief on your second

1877

01:10:15,010 --> 01:10:12,139

point which is that the exoplanet field

1878

01:10:19,089 --> 01:10:15,020

itself is relatively young right so I

1879

01:10:21,820 --> 01:10:19,099

started a few months before 51 peg B was

1880

01:10:24,490 --> 01:10:21,830

announced and I grew up with many of the

1881

01:10:26,620 --> 01:10:24,500

people that that I talked to on a

1882

01:10:28,240 --> 01:10:26,630

regular basis we grew up as graduate

1883

01:10:30,250 --> 01:10:28,250

students together when we could count

1884

01:10:33,490 --> 01:10:30,260

the number of exoplanets on one hand and

1885

01:10:35,229 --> 01:10:33,500

actually knew their names now it's 4,000

1886

01:10:36,700 --> 01:10:35,239

and some and yeah I don't have that

1887

01:10:40,720 --> 01:10:36,710

memory anymore

1888

01:10:42,459 --> 01:10:40,730

so I think in the ex for example in the

1889

01:10:44,500 --> 01:10:42,469

National Academy of Sciences exoplanet

1890

01:10:48,250 --> 01:10:44,510

science strategy we worked very very

1891

01:10:52,899 --> 01:10:48,260

hard to have exactly equal gender

1892

01:10:54,729 --> 01:10:52,909

balance in our committee was extremely

1893

01:10:58,060 --> 01:10:54,739

young in fact I was one of the oldest

1894

01:11:00,160 --> 01:10:58,070

people on the community and and that was

1895

01:11:01,930 --> 01:11:00,170

by that was intentional because that's

1896

01:11:03,879 --> 01:11:01,940

because the field itself is very young

1897

01:11:06,700 --> 01:11:03,889

and I think the astrobiology field is

1898

01:11:09,580 --> 01:11:06,710

probably even younger in many ways and

1899

01:11:11,740 --> 01:11:09,590

so I and then that speak and it's not

1900

01:11:14,140 --> 01:11:11,750

only nice to have the young people who

1901

01:11:15,879 --> 01:11:14,150

are invested in the future but it also

1902

01:11:18,220 --> 01:11:15,889

that also helps to increase the

1903

01:11:21,939 --> 01:11:18,230

diversity and the representation from

1904

01:11:24,729 --> 01:11:21,949

underrepresented groups yet by drawing

1905

01:11:26,500 --> 01:11:24,739

from a broader pool of people and so

1906

01:11:28,270 --> 01:11:26,510

that I think makes these committees and

1907

01:11:31,060 --> 01:11:28,280

this whole endeavor a bunch more

1908

01:11:34,240 --> 01:11:31,070

powerful and much more a much more

1909

01:11:36,520 --> 01:11:34,250

capable group of people than than if we

1910

01:11:42,760 --> 01:11:36,530

were drawing from the usual suspects

1911

01:11:44,260 --> 01:11:42,770

which I won't specify like me and and I

1912

01:11:45,640 --> 01:11:44,270

absolutely agree with that point too and

1913

01:11:47,379 --> 01:11:45,650

and since this plenary is kind of

1914

01:11:49,750 --> 01:11:47,389

supposed to pique your interest in feed

1915

01:11:51,220 --> 01:11:49,760

into the sessions that come afterwards I

1916

01:11:52,600 --> 01:11:51,230

want to give a shout out for the

1917

01:11:53,830 --> 01:11:52,610

characterizing exoplanets for how'd

1918

01:11:55,959 --> 01:11:53,840

ability and life session which will be

1919

01:11:57,669 --> 01:11:55,969

full of some absolutely fantastic early

1920

01:11:59,050 --> 01:11:57,679

career scientists I'm presenting their

1921

01:12:01,180 --> 01:11:59,060

work and in particular I wanted to give

1922

01:12:04,089 --> 01:12:01,190

a shout out to Jake rusty Yeager my talk

1923

01:12:06,430 --> 01:12:04,099

is pretty much jake's thesis and so go

1924

01:12:07,780 --> 01:12:06,440

go go listen to those talks and learn

1925

01:12:09,990 --> 01:12:07,790

more about this from the people who are

1926

01:12:13,450 --> 01:12:10,000

actually doing the work

1927

01:12:15,370 --> 01:12:13,460

here and then back over there yeah so I

1928

01:12:16,840 --> 01:12:15,380

was what Michael Schiavo I'm from

1929

01:12:18,700 --> 01:12:16,850

George's - technology I was just

1930

01:12:21,460 --> 01:12:18,710

wondering if there's any benefit to

1931

01:12:25,750 --> 01:12:21,470

using the Sun Shade with these other

1932

01:12:28,030 --> 01:12:25,760

mission architectures I'll say I guess

1933

01:12:28,330 --> 01:12:28,040

all they have to take that one so it's a

1934

01:12:30,820 --> 01:12:28,340

wheats

1935

01:12:32,560 --> 01:12:30,830

typically called a star shade friends

1936

01:12:35,020 --> 01:12:32,570

like all the space dayz whatever it

1937

01:12:38,650 --> 01:12:35,030

makes you happy it does look like a

1938

01:12:42,360 --> 01:12:38,660

daisy so the nice thing about the Stars

1939

01:12:44,590 --> 01:12:42,370

about a star star shade is that you can

1940

01:12:46,450 --> 01:12:44,600

let's see how do I say this in a play

1941

01:12:49,030 --> 01:12:46,460

way you can pretty much put any

1942

01:12:52,360 --> 01:12:49,040

telescope behind it and as long as it

1943

01:12:53,860 --> 01:12:52,370

has the collecting area and and it'll

1944

01:12:55,420 --> 01:12:53,870

it'll base and you know actually

1945

01:12:58,390 --> 01:12:55,430

reflects photons at the wavelengths you

1946

01:13:00,250 --> 01:12:58,400

want then it basically works fine and

1947

01:13:02,980 --> 01:13:00,260

that's the beauty of the star shade so

1948

01:13:05,200 --> 01:13:02,990

any sort of crappy wobbly telescope you

1949

01:13:07,000 --> 01:13:05,210

have whatever that's that's fine it just

1950

01:13:08,590 --> 01:13:07,010

has to have a significant at the truck

1951

01:13:11,320 --> 01:13:08,600

aperture to get the photons from the

1952

01:13:13,780 --> 01:13:11,330

planet so there is an endeavor led by

1953

01:13:16,300 --> 01:13:13,790

Sara Seager probe class mission study

1954

01:13:19,050 --> 01:13:16,310

called rendezvous which would rendezvous

1955

01:13:22,450 --> 01:13:19,060

with the W first Space Telescope and

1956

01:13:25,570 --> 01:13:22,460

enable direct imaging of exoplanets now

1957

01:13:27,730 --> 01:13:25,580

of course it won't be as capable as as

1958

01:13:29,980 --> 01:13:27,740

it have X or lukewarm eye any stretch of

1959

01:13:33,700 --> 01:13:29,990

the imagination it's a smaller star

1960

01:13:36,490 --> 01:13:33,710

shade it's a smaller aperture but it

1961

01:13:38,710 --> 01:13:36,500

will it will it will be able to do so a

1962

01:13:40,900 --> 01:13:38,720

lot of great science and furthermore it

1963

01:13:43,420 --> 01:13:40,910

will actually it demonstrate this

1964

01:13:45,610 --> 01:13:43,430

technology of a star shade which will

1965

01:13:48,280 --> 01:13:45,620

then enable future missions like have X

1966

01:13:50,140 --> 01:13:48,290

or or maybe a Louvre RB with a star

1967

01:13:53,230 --> 01:13:50,150

shade or a Louvre X or somewhere in

1968

01:13:54,370 --> 01:13:53,240

between so that's that's the one that's

1969

01:13:56,260 --> 01:13:54,380

one of the beautiful things about the

1970

01:13:59,230 --> 01:13:56,270

star shade is it it can be matched up

1971

01:14:01,330 --> 01:13:59,240

with any telescope even JWST for example

1972

01:14:04,900 --> 01:14:01,340

though that's has practical problems

1973

01:14:06,340 --> 01:14:04,910

otherwise like timing and I agree that

1974

01:14:08,530 --> 01:14:06,350

star shades are awesome they have

1975

01:14:10,780 --> 01:14:08,540

fantastic throughput convert to at least

1976

01:14:11,320 --> 01:14:10,790

current karna graphic designs I love

1977

01:14:13,120 --> 01:14:11,330

star shades

1978

01:14:15,250 --> 01:14:13,130

I cut a lot of my scientific teeth

1979

01:14:16,690 --> 01:14:15,260

working on observing exoplanets to start

1980

01:14:19,060 --> 01:14:16,700

shades as an undergrad at the University

1981

01:14:20,770 --> 01:14:19,070

of Colorado and the reason why Lou guar

1982

01:14:22,210 --> 01:14:20,780

doesn't have a star shade as part of its

1983

01:14:25,660 --> 01:14:22,220

baseline concept is because it would

1984

01:14:28,960 --> 01:14:25,670

have to be absolutely enormous possibly

1985

01:14:31,510 --> 01:14:28,970

too big to fit into a rocket and easily

1986

01:14:33,600 --> 01:14:31,520

so the star shade you know it grows with

1987

01:14:35,980 --> 01:14:33,610

the size of the telescope and so I

1988

01:14:37,330 --> 01:14:35,990

forget exactly how big the Lubar star

1989

01:14:39,370 --> 01:14:37,340

she would be I think it's like hundreds

1990

01:14:42,010 --> 01:14:39,380

oh yeah so Lubar a would be a hundred

1991

01:14:43,360 --> 01:14:42,020

meters or something but there's a one of

1992

01:14:47,040 --> 01:14:43,370

the appendices a hundred years but

1993

01:14:49,210 --> 01:14:47,050

there's designs of my community yeah so

1994

01:14:50,470 --> 01:14:49,220

truncated wavelength range if you wanted

1995

01:14:52,180 --> 01:14:50,480

to and then you could shrink your stars

1996

01:14:53,590 --> 01:14:52,190

right so I think a live wire you could

1997

01:14:55,420 --> 01:14:53,600

get away with the star shade that's not

1998

01:14:58,690 --> 01:14:55,430

much bigger than the 52 meters that have

1999

01:15:00,190 --> 01:14:58,700

X does so as much as I think those of us

2000

01:15:01,360 --> 01:15:00,200

but I'm working on have X and Lavar I

2001

01:15:03,460 --> 01:15:01,370

think that we're going to be done in

2002

01:15:05,710 --> 01:15:03,470

August when we submit our final reports

2003

01:15:07,600 --> 01:15:05,720

I suspect there's gonna be more work

2004

01:15:09,850 --> 01:15:07,610

that has to be done later to try to

2005

01:15:11,560 --> 01:15:09,860

bridge the gap between the Havoc's and

2006

01:15:13,450 --> 01:15:11,570

which is a four meter with a star shade

2007

01:15:15,520 --> 01:15:13,460

and Louvre RB which is eight meters

2008

01:15:17,470 --> 01:15:15,530

without a star shade to see if there's

2009

01:15:18,970 --> 01:15:17,480

some intermediate architecture that we

2010

01:15:21,400 --> 01:15:18,980

can take advantage of the star shade and

2011

01:15:22,180 --> 01:15:21,410

the chronograph apologies to the folks

2012

01:15:23,350 --> 01:15:22,190

still at the mics

2013

01:15:25,150 --> 01:15:23,360

I'm gonna have to move on to closing

2014

01:15:27,310 --> 01:15:25,160

remarks for the session so everyone can

2015

01:15:28,960 --> 01:15:27,320

get to coffee two things one if you

2016

01:15:30,760 --> 01:15:28,970

still have questions a couple great

2017

01:15:32,680 --> 01:15:30,770

places to ask them are coming up on the

2018

01:15:33,940 --> 01:15:32,690

agenda later this morning in this

2019

01:15:35,830 --> 01:15:33,950

afternoon first the character's

2020

01:15:37,510 --> 01:15:35,840

characterizing exoplanet habitability in

2021

01:15:39,010 --> 01:15:37,520

life a future space observatory sessions

2022

01:15:40,720 --> 01:15:39,020

one and two which vicki has mentioned a

2023

01:15:41,770 --> 01:15:40,730

few times actually these folks were

2024

01:15:43,120 --> 01:15:41,780

originally going to present in that

2025

01:15:44,680 --> 01:15:43,130

session they kind of got pulled up to

2026

01:15:46,090 --> 01:15:44,690

the plenary and we back filled with

2027

01:15:47,410 --> 01:15:46,100

early career folks so we're really

2028

01:15:48,880 --> 01:15:47,420

excited about that

2029

01:15:50,230 --> 01:15:48,890

and then second that you might have

2030

01:15:51,600 --> 01:15:50,240

heard me mention Carl's the chief

2031

01:15:53,920 --> 01:15:51,610

scientist for the NASA exoplanet

2032

01:15:56,710 --> 01:15:53,930

exploration program office and said what

2033

01:16:00,190 --> 01:15:56,720

is that well you can find out today at

2034

01:16:01,360 --> 01:16:00,200

lunch between 12:20 and 1:20 p.m. those

2035

01:16:03,430 --> 01:16:01,370

are both in the agenda if you need to

2036

01:16:04,750 --> 01:16:03,440

find this specific room and then lastly

2037

01:16:06,610 --> 01:16:04,760

this was mentioned as part of the panel

2038

01:16:09,280 --> 01:16:06,620

discussion and following dr. Pilcher's

2039

01:16:11,170 --> 01:16:09,290

comments I really do believe that all

2040

01:16:13,600 --> 01:16:11,180

scientific endeavors require diverse set

2041

01:16:14,470 --> 01:16:13,610

of voices to participate but I think

2042

01:16:16,060 --> 01:16:14,480

that's particularly true for

2043

01:16:17,290 --> 01:16:16,070

interdisciplinary endeavors such as the

2044

01:16:20,049 --> 01:16:17,300

ones where we heard about this morning

2045

01:16:21,790 --> 01:16:20,059

we'll hear about all week so in that to

2046

01:16:23,560 --> 01:16:21,800

support that we've got some events going

2047

01:16:26,260 --> 01:16:23,570

on at Epps icon this week starting with

2048

01:16:28,930 --> 01:16:26,270

tonight at 5:15 and allies and advocates

2049

01:16:31,240 --> 01:16:28,940

an astrobiology discussion on diversity

2050

01:16:33,520 --> 01:16:31,250

and inclusive inclusivity at 4:00 p.m.

2051
01:16:35,410 --> 01:16:33,530
on Wednesday a session on fostering

2052
01:16:38,439 --> 01:16:35,420
inclusive education practices from K to

2053
01:16:40,510 --> 01:16:38,449
12 two funding agencies and at 1:30 p.m.

2054
01:16:42,310 --> 01:16:40,520
on Thursday growing the astrobiology

2055
01:16:44,080 --> 01:16:42,320
field inviting K to 12 undergraduates

2056
01:16:45,549 --> 01:16:44,090
underrepresented groups citizen

2057
01:16:47,799 --> 01:16:45,559
scientists and the public into the

2058
01:16:49,720 --> 01:16:47,809
search for life and its origins and one

2059
01:16:50,950 --> 01:16:49,730
last announcement also tonight we have a

2060
01:16:52,870 --> 01:16:50,960
public event at the University of

2061
01:16:55,120 --> 01:16:52,880
Washington it is the public event for

2062
01:16:58,149 --> 01:16:55,130
this meeting it's only about a 10 minute

2063
01:16:59,709 --> 01:16:58,159

taxi uber lyft whatever a 20 minute ride

2064

01:17:01,330 --> 01:16:59,719

away across the bridge depending on how

2065

01:17:04,959 --> 01:17:01,340

much how many cars are on the bridge at

2066

01:17:06,459 --> 01:17:04,969

the time the title of that is the search

2067

01:17:08,350 --> 01:17:06,469

for extraterrestrial life what's it all

2068

01:17:10,720 --> 01:17:08,360

about we have a lot of our current and

2069

01:17:12,100 --> 01:17:10,730

former bloomberg chairs of astrobiology

2070

01:17:13,959 --> 01:17:12,110

at the Library of Congress that will be

2071

01:17:17,379 --> 01:17:13,969

part of that I'm looking forward to that

2072

01:17:18,939 --> 01:17:17,389

as well on so I hope you attend oh and

2073

01:17:21,339 --> 01:17:18,949

Morgan has something to announce

2074

01:17:23,950 --> 01:17:21,349

yes go ahead sorry Mary sent me up here

2075

01:17:25,390 --> 01:17:23,960

I'm part of the organizing committee my

2076
01:17:27,479 --> 01:17:25,400
name is Morgan cable and I just wanted

2077
01:17:29,530 --> 01:17:27,489
to point out in creating a safe

2078
01:17:31,689 --> 01:17:29,540
environments as part of this conference

2079
01:17:33,310 --> 01:17:31,699
we do have a code of conduct that's on

2080
01:17:35,620 --> 01:17:33,320
the apps icon website I encourage you to

2081
01:17:36,939 --> 01:17:35,630
check it out of course we have

2082
01:17:38,740 --> 01:17:36,949
absolutely zero tolerance for any

2083
01:17:40,780 --> 01:17:38,750
discrimination or harassment of any kind

2084
01:17:43,870 --> 01:17:40,790
if you do have any questions feel free

2085
01:17:46,959 --> 01:17:43,880
to stop and ask me Vikki or any of the

2086
01:17:48,310 --> 01:17:46,969
other members of the SOC and of course

2087
01:17:53,020 --> 01:17:48,320
if you see something say something

2088
01:17:55,450 --> 01:17:53,030

thank you thanks Morgan for that and

2089

01:17:57,250 --> 01:17:55,460

then lastly I want to do the the formal

2090

01:17:58,419 --> 01:17:57,260

thank-yous for the session I don't think

2091

01:18:00,790 --> 01:17:58,429

all of you for your attention I think

2092

01:18:02,859 --> 01:18:00,800

this is the largest and certainly the

2093

01:18:04,600 --> 01:18:02,869

most diverse audience that has seen the

2094

01:18:06,370 --> 01:18:04,610

presentation of these decadal survey

2095

01:18:09,220 --> 01:18:06,380

mission concepts so thank you for being

2096

01:18:11,740 --> 01:18:09,230

here thank you to the speakers and and

2097

01:18:13,540 --> 01:18:11,750

my co-chair and the SOC for letting us

2098

01:18:17,320 --> 01:18:13,550

have this today and thank you forever