PUBLIC LECTURE SERIES

How Yavin IV and Orbital Mechanics Destroyed the Death Star

Featuring Guest Speaker:
Mia Bovill

1
00:00:05,269 --> 00:00:03,909
welcome to the space telescope public

2
00:00:06,389 --> 00:00:05,279
lecture series

3
00:00:08,390 --> 00:00:06,399
tonight

4
00:00:10,950 --> 00:00:08,400
how yavin 4

5
00:00:13,910 --> 00:00:10,960
and orbital mechanics destroyed the

6
00:00:17,430 --> 00:00:13,920
death star from mia boval of texas

7
00:00:22,790 --> 00:00:20,710
i'm dr frank summers and as always i

8
00:00:24,950 --> 00:00:22,800
want to welcome you to our our

9
00:00:27,429 --> 00:00:24,960
presentation tonight and thank our

10
00:00:29,509 --> 00:00:27,439
amazing tech team thomas marufu and

11
00:00:32,389 --> 00:00:29,519
grant justice who take care of recording

12
00:00:34,870 --> 00:00:32,399
this and getting it out to youtube

13
00:00:38,310 --> 00:00:34,880

for our upcoming talks

14
00:00:41,110 --> 00:00:38,320
next month we have a kind of special one

15
00:00:43,990 --> 00:00:41,120
uh the web space telescope will be

16
00:00:47,910 --> 00:00:44,000
releasing their very first images on

17
00:00:51,910 --> 00:00:47,920
july 12th that's one week from today

18
00:00:54,470 --> 00:00:51,920
at 10 30 a.m eastern daylight time

19
00:00:56,150 --> 00:00:54,480
and on august 2nd we will have alex

20
00:00:58,229 --> 00:00:56,160
lockwood from the space telescope

21
00:01:01,029 --> 00:00:58,239
science institute discussing those

22
00:01:01,830 --> 00:01:01,039
images in her talk titled webb's first

23
00:01:04,229 --> 00:01:01,840
look

24
00:01:06,230 --> 00:01:04,239
images and spectra from nasa's newest

25
00:01:07,910 --> 00:01:06,240
great observatory

26
00:01:10,310 --> 00:01:07,920
in september

27
00:01:12,789 --> 00:01:10,320
uh guido roberts for asani from the

28
00:01:15,190 --> 00:01:12,799
university of california at los angeles

29
00:01:17,670 --> 00:01:15,200
we'll talk about very

30
00:01:20,710 --> 00:01:17,680
uh earl happenings in the very early

31
00:01:24,550 --> 00:01:20,720
universe uh first light unveiling the

32
00:01:26,550 --> 00:01:24,560
properties of galaxies at cosmic dawn

33
00:01:28,390 --> 00:01:26,560
and in october we're going to have

34
00:01:30,710 --> 00:01:28,400
another very interesting and very

35
00:01:33,749 --> 00:01:30,720
special talk for you um it's called the

36
00:01:36,069 --> 00:01:33,759
universe of dante allegherie and the

37
00:01:39,510 --> 00:01:36,079
speaker is a retired astronomer from

38
00:01:42,389 --> 00:01:39,520

italy named spirello de soregy

39
00:01:44,710 --> 00:01:42,399
a descendant of the original dante

40
00:01:47,910 --> 00:01:44,720
alleghery and he will go through dante's

41
00:01:50,310 --> 00:01:47,920
work and talk about his use of astronomy

42
00:01:52,389 --> 00:01:50,320
and the universal symbols that he used

43
00:01:54,710 --> 00:01:52,399
in his work

44
00:01:56,550 --> 00:01:54,720
you want to know more about when these

45
00:01:57,670 --> 00:01:56,560
uh these lectures you can go to our

46
00:02:01,670 --> 00:01:57,680
website

47
00:02:07,109 --> 00:02:04,550
public hyphen lectures

48
00:02:10,550 --> 00:02:07,119
on that you will find um a links to our

49
00:02:12,470 --> 00:02:10,560
webcasts as well as a way to subscribe

50
00:02:14,309 --> 00:02:12,480
to our emails

51
00:02:16,710 --> 00:02:14,319
just enter your email address and push

52
00:02:19,510 --> 00:02:16,720
that subscribe button

53
00:02:20,949 --> 00:02:19,520
you will find lists of upcoming lectures

54
00:02:23,430 --> 00:02:20,959
and when you click on one of these

55
00:02:25,990 --> 00:02:23,440
lectures you will get all of the details

56
00:02:28,470 --> 00:02:26,000
um including the speaker

57
00:02:31,750 --> 00:02:28,480
the description uh and after it has been

58
00:02:35,030 --> 00:02:31,760
recorded uh links to the space telescope

59
00:02:39,509 --> 00:02:35,040
uh webcast and the webcast as it is on

60
00:02:43,830 --> 00:02:41,750
as i said you can sign up for our email

61
00:02:46,470 --> 00:02:43,840
list on our website

62
00:02:48,790 --> 00:02:46,480
you can also subscribe to our youtube

63
00:02:51,910 --> 00:02:48,800

channel youtube.com

64
00:02:54,630 --> 00:02:51,920
hubble space telescope all one word uh

65
00:02:57,509 --> 00:02:54,640
you will get new notices of new videos

66
00:03:01,030 --> 00:02:57,519
and reminders of live events like this

67
00:03:02,550 --> 00:03:01,040
and if you have questions or comments uh

68
00:03:04,630 --> 00:03:02,560
other questions for the speaker that you

69
00:03:06,790 --> 00:03:04,640
didn't get to ask during the talk you

70
00:03:11,750 --> 00:03:06,800
can send them to public lecture at

71
00:03:15,110 --> 00:03:13,750
our social media accounts we have social

72
00:03:17,430 --> 00:03:15,120
media accounts for the hubble space

73
00:03:19,509 --> 00:03:17,440
telescope for the web space telescope

74
00:03:22,949 --> 00:03:19,519
and for the space telescope science

75
00:03:24,869 --> 00:03:22,959
institute on facebook twitter youtube

76
00:03:27,430 --> 00:03:24,879
and instagram

77
00:03:29,750 --> 00:03:27,440
i myself as i always say do a tiny

78
00:03:32,070 --> 00:03:29,760
amount of social media you can find me

79
00:03:35,589 --> 00:03:32,080
on facebook and twitter as dr frank

80
00:03:41,670 --> 00:03:38,229
news for the universe from the universe

81
00:03:44,789 --> 00:03:41,680
for july 2022

82
00:03:46,710 --> 00:03:44,799
our story tonight is about compact

83
00:03:49,030 --> 00:03:46,720
groups of galaxies

84
00:03:51,430 --> 00:03:49,040
now when you think of a galaxy you

85
00:03:53,509 --> 00:03:51,440
probably think of an isolated galaxy

86
00:03:54,789 --> 00:03:53,519
like this this is the sombrero galaxy

87
00:03:57,270 --> 00:03:54,799
and it's just a

88
00:03:59,910 --> 00:03:57,280

gorgeous galaxy here this is a got a

89
00:04:02,550 --> 00:03:59,920
broad disk and a huge bulge from this we

90
00:04:05,030 --> 00:04:02,560
call this a lenticular galaxy and people

91
00:04:07,670 --> 00:04:05,040
think of galaxies existing on their own

92
00:04:10,630 --> 00:04:07,680
but galaxies don't always exist on their

93
00:04:14,470 --> 00:04:10,640
own sometimes you can find them in pairs

94
00:04:15,550 --> 00:04:14,480
so for example this is ngc 2207

95
00:04:18,870 --> 00:04:15,560
and

96
00:04:20,229 --> 00:04:18,880
ic2163 i'm actually not sure which is

97
00:04:22,469 --> 00:04:20,239
which but

98
00:04:24,469 --> 00:04:22,479
these are two galaxies that are nearby

99
00:04:26,710 --> 00:04:24,479
each other in the universe they're sort

100
00:04:27,590 --> 00:04:26,720
of past one is passing in front of the

101
00:04:28,390 --> 00:04:27,600
other

102
00:04:31,189 --> 00:04:28,400
these

103
00:04:32,390 --> 00:04:31,199
galaxies are not interacting

104
00:04:33,990 --> 00:04:32,400
yet

105
00:04:36,950 --> 00:04:34,000
but they are close

106
00:04:39,909 --> 00:04:36,960
and actually when i think of galaxy

107
00:04:42,710 --> 00:04:39,919
pairs i generally think of galaxies that

108
00:04:45,350 --> 00:04:42,720
have interacted such as these this is

109
00:04:47,189 --> 00:04:45,360
the mice galaxies okay two galaxies that

110
00:04:49,590 --> 00:04:47,199
have come past each other and they

111
00:04:51,350 --> 00:04:49,600
pulled out these big long tidal tails

112
00:04:52,710 --> 00:04:51,360
from each other you can see the cores

113
00:04:55,350 --> 00:04:52,720

and they're probably going to merge

114
00:04:56,710 --> 00:04:55,360
together and form a galaxy

115
00:04:58,230 --> 00:04:56,720
the other time

116
00:05:00,790 --> 00:04:58,240
clumping of galaxies that we tend to

117
00:05:02,790 --> 00:05:00,800
talk about are clusters of galaxies and

118
00:05:04,950 --> 00:05:02,800
so this is the perseus cluster of

119
00:05:06,390 --> 00:05:04,960
galaxies from the sloan digital

120
00:05:08,710 --> 00:05:06,400
sky survey

121
00:05:10,629 --> 00:05:08,720
and you can see there are dozens to you

122
00:05:13,270 --> 00:05:10,639
know hundreds of galaxies

123
00:05:15,350 --> 00:05:13,280
here in the uh in this cluster and when

124
00:05:18,230 --> 00:05:15,360
we talk about clusters we often talk

125
00:05:20,310 --> 00:05:18,240
about these huge huge clusters like

126
00:05:23,510 --> 00:05:20,320
abell 1689

127
00:05:26,150 --> 00:05:23,520
where the mass is so concentrated that

128
00:05:27,749 --> 00:05:26,160
gr that general relativity comes in

129
00:05:30,310 --> 00:05:27,759
um and the mass

130
00:05:32,710 --> 00:05:30,320
warps the space all right and when you

131
00:05:34,550 --> 00:05:32,720
look through that warp space you see

132
00:05:37,510 --> 00:05:34,560
lots of stretched out galaxies you see

133
00:05:40,790 --> 00:05:37,520
what's called gravitational lensing on

134
00:05:43,270 --> 00:05:40,800
abell 1689 is a really good example and

135
00:05:45,189 --> 00:05:43,280
here are all these stretched arc arcs

136
00:05:46,710 --> 00:05:45,199
these are galaxies on the far side of

137
00:05:48,390 --> 00:05:46,720
the cluster whose light has gotten

138
00:05:50,950 --> 00:05:48,400

stretched out

139
00:05:53,430 --> 00:05:50,960
while passing through that cluster all

140
00:05:55,029 --> 00:05:53,440
right so we think of individual galaxies

141
00:05:56,870 --> 00:05:55,039
we think of pairs of galaxies we think

142
00:05:57,670 --> 00:05:56,880
of clusters of galaxies

143
00:06:00,390 --> 00:05:57,680
but

144
00:06:02,950 --> 00:06:00,400
there's another scale of galaxies that

145
00:06:04,950 --> 00:06:02,960
doesn't get as much play but it's kind

146
00:06:08,309 --> 00:06:04,960
of important for us

147
00:06:10,790 --> 00:06:08,319
why because we live in a group of

148
00:06:14,790 --> 00:06:10,800
galaxies all right this is an artist

149
00:06:16,870 --> 00:06:14,800
depiction of the local group of galaxies

150
00:06:18,550 --> 00:06:16,880
which as you can see has our milky way

151
00:06:21,990 --> 00:06:18,560
galaxy in it

152
00:06:24,070 --> 00:06:22,000
and has about three dozen other galaxies

153
00:06:28,469 --> 00:06:24,080
um it's not a really

154
00:06:30,150 --> 00:06:28,479
big group of galaxies okay um it's uh

155
00:06:32,150 --> 00:06:30,160
only got three

156
00:06:34,390 --> 00:06:32,160
big size galaxies okay so it's got the

157
00:06:36,309 --> 00:06:34,400
milky way which is a large galaxy it's

158
00:06:37,430 --> 00:06:36,319
got andromeda which is a slightly larger

159
00:06:42,070 --> 00:06:37,440
galaxy

160
00:06:43,990 --> 00:06:42,080
also known as m33 which is sort of a

161
00:06:45,270 --> 00:06:44,000
medium-sized galaxy

162
00:06:47,510 --> 00:06:45,280
everything else in the three dozen

163
00:06:50,150 --> 00:06:47,520

galaxies in our local group are all

164
00:06:52,710 --> 00:06:50,160
small galaxies and so it's not really

165
00:06:55,110 --> 00:06:52,720
the most photogenic of uh when it comes

166
00:06:56,710 --> 00:06:55,120
to groups of galaxies uh actually it's

167
00:06:58,550 --> 00:06:56,720
impossibly photogenic because we're in

168
00:07:00,070 --> 00:06:58,560
the milky way galaxy we can't get out to

169
00:07:02,550 --> 00:07:00,080
get this picture so that's why we have

170
00:07:05,270 --> 00:07:02,560
to rely on artists drawing of it if you

171
00:07:07,350 --> 00:07:05,280
want to take a really beautiful

172
00:07:09,350 --> 00:07:07,360
a group group of galaxies one of the

173
00:07:12,870 --> 00:07:09,360
most famous that people know

174
00:07:15,830 --> 00:07:12,880
is this one which is stefan's quintet

175
00:07:17,589 --> 00:07:15,840
quintet having five galaxies uh you can

176
00:07:20,950 --> 00:07:17,599
see that this central one here is

177
00:07:23,990 --> 00:07:20,960
actually two galaxies merging together

178
00:07:27,189 --> 00:07:24,000
but stefan's quintet is also not really

179
00:07:31,110 --> 00:07:27,199
a quintet because this galaxy here in

180
00:07:33,510 --> 00:07:31,120
the foreground this blue one is actually

181
00:07:36,309 --> 00:07:33,520
not part of a group okay it happens just

182
00:07:39,029 --> 00:07:36,319
to be projected along the line of sight

183
00:07:41,830 --> 00:07:39,039
it's about one-third the distance of the

184
00:07:44,629 --> 00:07:41,840
other four galaxies in it okay

185
00:07:47,749 --> 00:07:44,639
so there are these groups of galaxies

186
00:07:50,070 --> 00:07:47,759
and for hubble's 32nd anniversary

187
00:07:52,390 --> 00:07:50,080
we had another really beautiful

188
00:07:53,430 --> 00:07:52,400

photogenic group of galaxies

189
00:07:56,950 --> 00:07:53,440
called

190
00:07:59,830 --> 00:07:56,960
hixon's compact group 40.

191
00:08:02,309 --> 00:07:59,840
hixon paul hickson was an astronomer who

192
00:08:03,990 --> 00:08:02,319
became fascinated with these comp groups

193
00:08:06,950 --> 00:08:04,000
uh and then particularly the groups that

194
00:08:10,150 --> 00:08:06,960
appeared very compact on the sky

195
00:08:12,070 --> 00:08:10,160
uh because the thing is if galaxies are

196
00:08:14,230 --> 00:08:12,080
this compact if they're physically that

197
00:08:15,909 --> 00:08:14,240
close together well then they're going

198
00:08:17,589 --> 00:08:15,919
to merge together they're going to

199
00:08:19,990 --> 00:08:17,599
interact and they're going to basically

200
00:08:22,390 --> 00:08:20,000
you know become one

201
00:08:24,390 --> 00:08:22,400
individual galaxy event eventually the

202
00:08:26,309 --> 00:08:24,400
what we call the dynamical time the time

203
00:08:29,029 --> 00:08:26,319
it takes for them to merge and mix

204
00:08:32,070 --> 00:08:29,039
together isn't that long compared to the

205
00:08:35,670 --> 00:08:32,080
age of the universe so finding a lot of

206
00:08:37,990 --> 00:08:35,680
these uh compact groups uh paul found

207
00:08:39,589 --> 00:08:38,000
over a hundred of these uh groups of

208
00:08:42,310 --> 00:08:39,599
galaxies

209
00:08:44,710 --> 00:08:42,320
sort of tells us something about how

210
00:08:45,910 --> 00:08:44,720
things are going in the universe um and

211
00:08:47,910 --> 00:08:45,920
so

212
00:08:50,630 --> 00:08:47,920
you can see that there are interactions

213
00:08:53,350 --> 00:08:50,640

going on in this okay uh so if you look

214
00:08:56,949 --> 00:08:53,360
at this central galaxy here okay the the

215
00:08:59,269 --> 00:08:56,959
the um title the spiral arms are pulled

216
00:09:00,710 --> 00:08:59,279
out just a little bit and stretched out

217
00:09:02,470 --> 00:09:00,720
and if you look at the one here on the

218
00:09:04,630 --> 00:09:02,480
upper left it's kind of hard to see

219
00:09:08,150 --> 00:09:04,640
because the the gas is all dark in it

220
00:09:10,550 --> 00:09:08,160
but there is a um title arm its spiral

221
00:09:12,550 --> 00:09:10,560
arm that's been pulled out really

222
00:09:15,990 --> 00:09:12,560
stretched out on that so you can see

223
00:09:17,430 --> 00:09:16,000
there have been uh interactions and the

224
00:09:20,150 --> 00:09:17,440
interesting thing about this group is

225
00:09:21,670 --> 00:09:20,160
that it's really it's a very compact

226
00:09:23,350 --> 00:09:21,680
compact group

227
00:09:25,590 --> 00:09:23,360
because if you look at the size of the

228
00:09:27,590 --> 00:09:25,600
elliptical galaxy here the the

229
00:09:30,230 --> 00:09:27,600
stretching from the top left to the

230
00:09:33,110 --> 00:09:30,240
bottom right is about two two and a half

231
00:09:34,710 --> 00:09:33,120
times that okay so if these galaxies

232
00:09:36,550 --> 00:09:34,720
were all at the exact same distance

233
00:09:38,470 --> 00:09:36,560
they'd be merging together

234
00:09:40,470 --> 00:09:38,480
so really what's what's going on here is

235
00:09:42,230 --> 00:09:40,480
they all are unlike

236
00:09:43,990 --> 00:09:42,240
stefan's quintet there are no foreground

237
00:09:45,350 --> 00:09:44,000
galaxies here they're all pretty much

238
00:09:47,910 --> 00:09:45,360

the same but they have to be sort of

239
00:09:50,389 --> 00:09:47,920
stretched out along the line of sight so

240
00:09:51,590 --> 00:09:50,399
it's like we're looking down a a pipe of

241
00:09:53,829 --> 00:09:51,600
galaxies

242
00:09:55,670 --> 00:09:53,839
and in order to get that idea across in

243
00:09:57,590 --> 00:09:55,680
our press release well

244
00:09:59,350 --> 00:09:57,600
we made a video

245
00:10:02,310 --> 00:09:59,360
so this is a

246
00:10:08,360 --> 00:10:02,320
zoom into and fly through a 3d fly

247
00:11:16,310 --> 00:10:27,370
[Music]

248
00:11:20,790 --> 00:11:18,389
and that was our

249
00:11:23,110 --> 00:11:20,800
happy anniversary uh present to the

250
00:11:28,230 --> 00:11:23,120
hobble space telescope for its 32nd

251
00:11:31,590 --> 00:11:29,030
so

252
00:11:34,870 --> 00:11:31,600
our speaker tonight

253
00:11:36,150 --> 00:11:34,880
uh is mia bovo from texas christian

254
00:11:40,550 --> 00:11:36,160
university

255
00:11:42,470 --> 00:11:40,560
of maryland here

256
00:11:45,670 --> 00:11:42,480
uh in maryland where

257
00:11:49,190 --> 00:11:45,680
i am um and then she did a postdoc down

258
00:11:51,030 --> 00:11:49,200
in santiago chile where she did some uh

259
00:11:53,190 --> 00:11:51,040
wonderful research down there and then

260
00:11:54,829 --> 00:11:53,200
came up to us here at the space

261
00:11:57,509 --> 00:11:54,839
telescope science institute here in

262
00:12:00,150 --> 00:11:57,519
baltimore uh and joined us for a few

263
00:12:02,069 --> 00:12:00,160

years and then we lost her and she went

264
00:12:05,030 --> 00:12:02,079
off to tesco's christian university

265
00:12:06,230 --> 00:12:05,040
where she is now an assistant professor

266
00:12:08,389 --> 00:12:06,240
um

267
00:12:09,829 --> 00:12:08,399
her research is

268
00:12:12,949 --> 00:12:09,839
as you might guess

269
00:12:14,949 --> 00:12:12,959
not into star wars uh she does not get

270
00:12:18,069 --> 00:12:14,959
paid to do star wars she does that on

271
00:12:20,870 --> 00:12:18,079
her own time uh if you remember a few

272
00:12:24,150 --> 00:12:20,880
years ago she gave a talk on star trek

273
00:12:24,949 --> 00:12:24,160
um and uh so she is definitely a sci-fi

274
00:12:27,110 --> 00:12:24,959
geek

275
00:12:29,350 --> 00:12:27,120
um and she tells me that one of her

276
00:12:31,590 --> 00:12:29,360
favorite hobbies is playing with her cat

277
00:12:34,310 --> 00:12:31,600
named minerba which should also tell you

278
00:12:35,590 --> 00:12:34,320
that she's a bit of a harry potter geek

279
00:12:37,910 --> 00:12:35,600
as well

280
00:12:41,110 --> 00:12:37,920
but her actual research when she's not

281
00:12:43,030 --> 00:12:41,120
doing sci-fi or playing with her cat

282
00:12:46,710 --> 00:12:43,040
is on the formation and fate of the

283
00:12:49,389 --> 00:12:46,720
first stars in galaxies um and as she

284
00:12:52,550 --> 00:12:49,399
said as we were prepping for this she is

285
00:12:54,629 --> 00:12:52,560
unbelievably excited

286
00:12:57,990 --> 00:12:54,639
for their new results from web next

287
00:13:07,829 --> 00:12:58,000
month so ladies and gentlemen

288
00:13:13,590 --> 00:13:10,629

all right hello rebels imperialists and

289
00:13:14,470 --> 00:13:13,600
um the occasional botham spy

290
00:13:16,470 --> 00:13:14,480
um

291
00:13:18,790 --> 00:13:16,480
i'm going to be talking to you about how

292
00:13:21,990 --> 00:13:18,800
yavin 4 and orbital mechanics destroyed

293
00:13:24,069 --> 00:13:22,000
the death star which is also a lovely

294
00:13:26,230 --> 00:13:24,079
gateway to talk to you about all of the

295
00:13:28,550 --> 00:13:26,240
phenomenal things that we've discovered

296
00:13:31,269 --> 00:13:28,560
about exoplanets since george lucas

297
00:13:33,430 --> 00:13:31,279
released the first episode of his magnum

298
00:13:36,949 --> 00:13:33,440
opus

299
00:13:38,470 --> 00:13:36,959
before we go on all images um in this

300
00:13:40,310 --> 00:13:38,480
talk that are recognizable from star

301
00:13:41,430 --> 00:13:40,320
wars are of course the property of

302
00:13:43,030 --> 00:13:41,440
disney

303
00:13:44,949 --> 00:13:43,040
and they are being used in this public

304
00:13:48,629 --> 00:13:44,959
lecture for educational purposes under

305
00:13:54,949 --> 00:13:53,910
so a long time ago in a galaxy far far

306
00:13:58,310 --> 00:13:54,959
uh

307
00:14:02,790 --> 00:14:00,550
the speed of light is constant in fact

308
00:14:05,430 --> 00:14:02,800
the speed of light is the speed limit of

309
00:14:06,790 --> 00:14:05,440
the universe so nothing can go faster

310
00:14:08,790 --> 00:14:06,800
than light

311
00:14:10,949 --> 00:14:08,800
this means that when we look out into

312
00:14:12,790 --> 00:14:10,959
the universe we are actually looking

313
00:14:14,550 --> 00:14:12,800

back in time

314
00:14:17,189 --> 00:14:14,560
it takes light about eight and a half

315
00:14:18,949 --> 00:14:17,199
minutes to get from the sun to the earth

316
00:14:20,389 --> 00:14:18,959
so when we look up at the sun and please

317
00:14:22,629 --> 00:14:20,399
don't look directly at the sun without

318
00:14:24,949 --> 00:14:22,639
proper equipment you're actually looking

319
00:14:26,949 --> 00:14:24,959
at the sun as it was eight and a half

320
00:14:28,710 --> 00:14:26,959
minutes ago this means that if the sun

321
00:14:31,750 --> 00:14:28,720
were to wake out of existence we'd have

322
00:14:33,750 --> 00:14:31,760
eight and a half minutes of complete and

323
00:14:35,509 --> 00:14:33,760
utter blissful ignorance before we found

324
00:14:36,310 --> 00:14:35,519
out about it

325
00:14:37,829 --> 00:14:36,320
and

326
00:14:40,629 --> 00:14:37,839
this means that the nearest stars in our

327
00:14:43,750 --> 00:14:40,639
galaxy we are seen as they were

328
00:14:45,430 --> 00:14:43,760
for alpha centauri four years ago

329
00:14:49,030 --> 00:14:45,440
beetlejuice if everyone remembers we

330
00:14:51,269 --> 00:14:49,040
thought it might go supernova it's 600

331
00:14:53,430 --> 00:14:51,279
light years away so beetlejuice might

332
00:14:55,350 --> 00:14:53,440
have actually already blown up we did

333
00:14:57,829 --> 00:14:55,360
the light from that explosion just

334
00:15:00,230 --> 00:14:57,839
hasn't reached us

335
00:15:02,870 --> 00:15:00,240
and this gets with this turns astronomy

336
00:15:05,670 --> 00:15:02,880
into a time machine the further out we

337
00:15:07,509 --> 00:15:05,680
look the further back in time we look

338
00:15:10,230 --> 00:15:07,519

the image on

339
00:15:13,030 --> 00:15:10,240
the left is that of the andromeda galaxy

340
00:15:16,150 --> 00:15:13,040
2.5 million light years away

341
00:15:17,030 --> 00:15:16,160
and we see the andromeda galaxy as the

342
00:15:22,870 --> 00:15:17,040
as

343
00:15:25,189 --> 00:15:22,880
now the good news is that because

344
00:15:26,870 --> 00:15:25,199
galaxies evolve over billions and

345
00:15:29,110 --> 00:15:26,880
billions of years

346
00:15:32,150 --> 00:15:29,120
seeing a galaxy as it was a few million

347
00:15:34,310 --> 00:15:32,160
years ago isn't that big of a deal

348
00:15:35,910 --> 00:15:34,320
but the image to the right is the hubble

349
00:15:38,710 --> 00:15:35,920
ultra deep field

350
00:15:40,870 --> 00:15:38,720
and until the amazing things that i know

351
00:15:43,670 --> 00:15:40,880
we're going to come out of jwst this was

352
00:15:45,990 --> 00:15:43,680
one of the deepest images ever taken

353
00:15:49,269 --> 00:15:46,000
every point of light in this image is

354
00:15:51,990 --> 00:15:49,279
not a star it is a galaxy and some of

355
00:15:53,670 --> 00:15:52,000
these galaxies are 10 billion light

356
00:15:55,189 --> 00:15:53,680
years away

357
00:15:57,189 --> 00:15:55,199
that means that when we're looking at

358
00:15:59,910 --> 00:15:57,199
the galaxies in this image we are seeing

359
00:16:03,030 --> 00:15:59,920
them as they were only about 300 million

360
00:16:03,990 --> 00:16:03,040
years 300 billion years after the big

361
00:16:05,829 --> 00:16:04,000
bang

362
00:16:08,150 --> 00:16:05,839
so what does this have to do with star

363
00:16:10,550 --> 00:16:08,160

wars well

364
00:16:13,350 --> 00:16:10,560
if far far away

365
00:16:14,790 --> 00:16:13,360
over long long ago is about equal to the

366
00:16:16,710 --> 00:16:14,800
speed of light

367
00:16:19,350 --> 00:16:16,720
that means that if we had a powerful

368
00:16:20,870 --> 00:16:19,360
enough telescope we could actually look

369
00:16:22,870 --> 00:16:20,880
at the galaxy in which star wars is

370
00:16:25,910 --> 00:16:22,880
happening and literally watch the

371
00:16:27,110 --> 00:16:25,920
millennium falcon doing the kessel run

372
00:16:29,670 --> 00:16:27,120
um

373
00:16:31,509 --> 00:16:29,680
however i hate to tell you that jwst is

374
00:16:33,910 --> 00:16:31,519
actually not even powerful enough to do

375
00:16:35,670 --> 00:16:33,920
this and we will have to wait many more

376
00:16:39,189 --> 00:16:35,680
years for far far more power for

377
00:16:41,269 --> 00:16:39,199
telescopes before we could do this

378
00:16:43,350 --> 00:16:41,279
so now back to yavin 4 and the death

379
00:16:45,189 --> 00:16:43,360
star

380
00:16:47,670 --> 00:16:45,199
so we've all seen this image this is the

381
00:16:49,350 --> 00:16:47,680
rebel base at yavin 4. um it at the

382
00:16:53,110 --> 00:16:49,360
actual site where they did this is the

383
00:16:54,990 --> 00:16:53,120
mayan city of takal in guatemala um the

384
00:16:57,269 --> 00:16:55,000
mayans actually are phenomenal

385
00:16:59,430 --> 00:16:57,279
archaeoastronomers some of the best in

386
00:17:01,590 --> 00:16:59,440
the ancient world they had nearly

387
00:17:03,590 --> 00:17:01,600
figured out the orbit of venus but that

388
00:17:05,350 --> 00:17:03,600

isn't topic for another talk in another

389
00:17:07,590 --> 00:17:05,360
time

390
00:17:09,270 --> 00:17:07,600
but in this image we actually see some

391
00:17:12,470 --> 00:17:09,280
things that are very important to

392
00:17:15,029 --> 00:17:12,480
figuring out what the yavin system is

393
00:17:17,350 --> 00:17:15,039
actually like and where yavin 4 and the

394
00:17:18,549 --> 00:17:17,360
gas giant is orbiting are located in the

395
00:17:21,029 --> 00:17:18,559
system

396
00:17:23,990 --> 00:17:21,039
for starters you see all this green

397
00:17:24,949 --> 00:17:24,000
there is life there there is complex

398
00:17:26,630 --> 00:17:24,959
life

399
00:17:30,230 --> 00:17:26,640
which in where and where you have

400
00:17:32,549 --> 00:17:30,240
complex life you very likely have water

401
00:17:34,549 --> 00:17:32,559
you also have these lovely buildings

402
00:17:36,710 --> 00:17:34,559
which are clearly built by some ancient

403
00:17:39,909 --> 00:17:36,720
civilization that potentially grew up on

404
00:17:42,150 --> 00:17:39,919
this moon which means that the climate

405
00:17:44,150 --> 00:17:42,160
and the orbit of this moon was stable

406
00:17:46,390 --> 00:17:44,160
enough over millions and millions

407
00:17:48,789 --> 00:17:46,400
potentially even billions of years

408
00:17:50,390 --> 00:17:48,799
to allow this civilization and complex

409
00:17:52,950 --> 00:17:50,400
life to evolve

410
00:17:55,430 --> 00:17:52,960
and if our rebel turns and when our

411
00:17:57,909 --> 00:17:55,440
rebel turns around you see that they are

412
00:18:00,390 --> 00:17:57,919
not wearing any kind of an oxygen mask

413
00:18:02,710 --> 00:18:00,400

or breathing apparatus which means that

414
00:18:05,590 --> 00:18:02,720
the atmosphere of this moon is an oxygen

415
00:18:07,990 --> 00:18:05,600
nitrogen atmosphere

416
00:18:09,669 --> 00:18:08,000
so what does all of this tell us

417
00:18:11,669 --> 00:18:09,679
well we have a rebel base but more

418
00:18:15,270 --> 00:18:11,679
importantly we have a jungle and an

419
00:18:17,990 --> 00:18:15,280
oxygen nitrogen atmosphere and to have

420
00:18:21,190 --> 00:18:18,000
oxygen specifically o2

421
00:18:23,669 --> 00:18:21,200
you need to have life

422
00:18:27,350 --> 00:18:23,679
the o2 spectral line that you can see

423
00:18:29,750 --> 00:18:27,360
here for a super earth and for an earth

424
00:18:32,230 --> 00:18:29,760
is one of the most important spectral

425
00:18:33,430 --> 00:18:32,240
lines that we can detect in an exoplanet

426
00:18:36,630 --> 00:18:33,440
atmosphere

427
00:18:39,270 --> 00:18:36,640
if we see a strong o2 line in an

428
00:18:41,590 --> 00:18:39,280
exoplanet atmosphere that is a very very

429
00:18:43,669 --> 00:18:41,600
strong indicator that there is life on

430
00:18:46,390 --> 00:18:43,679
that world

431
00:18:47,430 --> 00:18:46,400
and to have life you need some form of

432
00:18:49,430 --> 00:18:47,440
liquid

433
00:18:52,549 --> 00:18:49,440
you need some form of

434
00:18:55,190 --> 00:18:52,559
relatively innocuous substance in liquid

435
00:18:58,070 --> 00:18:55,200
form and the most common the best of

436
00:19:00,870 --> 00:18:58,080
these is of course water so you need

437
00:19:03,590 --> 00:19:00,880
liquid water

438
00:19:04,950 --> 00:19:03,600

which brings us to the habitable zone or

439
00:19:07,590 --> 00:19:04,960
the you might have also heard of this

440
00:19:09,350 --> 00:19:07,600
called the goldilocks zone

441
00:19:11,430 --> 00:19:09,360
so you have a star at the center of a

442
00:19:13,750 --> 00:19:11,440
solar system and that is the heat source

443
00:19:16,630 --> 00:19:13,760
for the entire solar system if there's

444
00:19:18,710 --> 00:19:16,640
no if it there is no other source of

445
00:19:20,549 --> 00:19:18,720
heat that doesn't effectively come from

446
00:19:23,029 --> 00:19:20,559
the main star

447
00:19:25,669 --> 00:19:23,039
if you were too close to the star

448
00:19:27,590 --> 00:19:25,679
the water will be in a gaseous will be

449
00:19:29,830 --> 00:19:27,600
in a gaseous state and it actually will

450
00:19:32,150 --> 00:19:29,840
eventually evaporate

451
00:19:33,750 --> 00:19:32,160
dissociate and evaporate off of the

452
00:19:37,510 --> 00:19:33,760
surface of the planets

453
00:19:40,070 --> 00:19:37,520
leaving a dry barren world like mercury

454
00:19:43,270 --> 00:19:40,080
and actually venus despite its very

455
00:19:45,270 --> 00:19:43,280
thick atmosphere is also very dry

456
00:19:47,909 --> 00:19:45,280
if you were too far out you were too

457
00:19:50,070 --> 00:19:47,919
cold and the water freezes and you end

458
00:19:52,710 --> 00:19:50,080
up with ice worlds

459
00:19:55,029 --> 00:19:52,720
things that we see europa ganymede the

460
00:19:56,950 --> 00:19:55,039
outer all the outer planets are ice

461
00:20:00,150 --> 00:19:56,960
worlds

462
00:20:01,430 --> 00:20:00,160
and if you're just right

463
00:20:03,190 --> 00:20:01,440

it's just

464
00:20:05,510 --> 00:20:03,200
warm enough that the water doesn't

465
00:20:07,270 --> 00:20:05,520
freeze but you're cool enough that it

466
00:20:10,070 --> 00:20:07,280
doesn't form a gas and this is the

467
00:20:12,390 --> 00:20:10,080
goldilocks zone or the habitable zone

468
00:20:15,830 --> 00:20:12,400
it's the area around a star where liquid

469
00:20:20,710 --> 00:20:18,710
and as as the luminosity of a star

470
00:20:23,029 --> 00:20:20,720
increases so the total energy output of

471
00:20:25,830 --> 00:20:23,039
a star increases the habitable zone will

472
00:20:27,270 --> 00:20:25,840
move further and further out from the

473
00:20:29,270 --> 00:20:27,280
star

474
00:20:30,870 --> 00:20:29,280
and something that you might notice here

475
00:20:33,830 --> 00:20:30,880
when we look at the habitable zone for

476
00:20:35,990 --> 00:20:33,840
our sun is that mars is actually just

477
00:20:38,070 --> 00:20:36,000
inside the outer edge of the habitable

478
00:20:40,149 --> 00:20:38,080
zone for our sun

479
00:20:43,590 --> 00:20:40,159
and what happened to mars is again a

480
00:20:46,310 --> 00:20:43,600
topic for another talk and another time

481
00:20:49,750 --> 00:20:46,320
so what kind of star

482
00:20:51,270 --> 00:20:49,760
is yavin is yavin for and yavin prime

483
00:20:53,430 --> 00:20:51,280
orbiting

484
00:20:55,909 --> 00:20:53,440
it's more likely than not that it's act

485
00:20:57,909 --> 00:20:55,919
they're actually orbiting a relatively

486
00:20:59,830 --> 00:20:57,919
sun-like star

487
00:21:03,669 --> 00:20:59,840
and the reason that we know this is

488
00:21:06,950 --> 00:21:03,679

because m dwarfs like galize 581

489
00:21:09,430 --> 00:21:06,960
are extremely active they shoot giant

490
00:21:11,590 --> 00:21:09,440
flares off of their surfaces

491
00:21:13,270 --> 00:21:11,600
and when they shoot these giant flares

492
00:21:16,230 --> 00:21:13,280
off of their surfaces

493
00:21:17,909 --> 00:21:16,240
they will hit and radiate planets in

494
00:21:20,149 --> 00:21:17,919
their habitable zone

495
00:21:22,390 --> 00:21:20,159
because remember their goldilocks zone

496
00:21:25,110 --> 00:21:22,400
is much closer to their star

497
00:21:27,029 --> 00:21:25,120
than out where about 1au where our suns

498
00:21:28,830 --> 00:21:27,039
is and so it would be

499
00:21:31,430 --> 00:21:28,840
potentially very difficult or very

500
00:21:34,789 --> 00:21:31,440
challenging for life to arrive for

501
00:21:36,149 --> 00:21:34,799
complex life to arise on a planet around

502
00:21:37,029 --> 00:21:36,159
an m dwarf

503
00:21:38,470 --> 00:21:37,039
but

504
00:21:39,669 --> 00:21:38,480
as we're going to sort of see when we

505
00:21:41,830 --> 00:21:39,679
really start talking about the

506
00:21:43,669 --> 00:21:41,840
exoplanets that we found we've learned

507
00:21:48,789 --> 00:21:43,679
to never say never when it comes to the

508
00:21:53,190 --> 00:21:50,710
so what do we actually know about the

509
00:21:54,950 --> 00:21:53,200
color of yavin prime so one of the

510
00:21:56,870 --> 00:21:54,960
images that is i think probably one of

511
00:21:59,430 --> 00:21:56,880
the most famous images of star wars is

512
00:22:01,510 --> 00:21:59,440
the one that i opened this talk with

513
00:22:03,430 --> 00:22:01,520

which is the rebel which is the scrappy

514
00:22:05,510 --> 00:22:03,440
rebel fleet going into battle against

515
00:22:08,230 --> 00:22:05,520
the death star under the backdrop of the

516
00:22:11,270 --> 00:22:08,240
bright red gas giant

517
00:22:13,430 --> 00:22:11,280
but would a gas giant

518
00:22:15,669 --> 00:22:13,440
orbiting around its

519
00:22:16,549 --> 00:22:15,679
orbiting around a star in the habitable

520
00:22:18,230 --> 00:22:16,559
zone

521
00:22:22,710 --> 00:22:18,240
actually be

522
00:22:28,870 --> 00:22:23,669
and

523
00:22:31,750 --> 00:22:28,880
combination of the types of chemicals in

524
00:22:33,190 --> 00:22:31,760
its atmosphere the types of molecules in

525
00:22:35,270 --> 00:22:33,200
its atmosphere and

526
00:22:37,270 --> 00:22:35,280
how those molecules are interacting with

527
00:22:39,830 --> 00:22:37,280
the radiation from the star and a

528
00:22:42,789 --> 00:22:39,840
beautiful example of this is from our

529
00:22:44,950 --> 00:22:42,799
own solar system this is a spectacular

530
00:22:47,990 --> 00:22:44,960
image actually of the aurora on jupiter

531
00:22:49,190 --> 00:22:48,000
taken by nasa's juno spacecraft and one

532
00:22:50,710 --> 00:22:49,200
of the most

533
00:22:54,390 --> 00:22:50,720
things that we all know about jupiter

534
00:22:56,230 --> 00:22:54,400
are these beautiful bands of color you

535
00:22:58,710 --> 00:22:56,240
see the white you see the white clouds

536
00:23:01,830 --> 00:22:58,720
and we have the red bands you have some

537
00:23:03,510 --> 00:23:01,840
sort of beige up here we all know about

538
00:23:06,070 --> 00:23:03,520

the great red spot

539
00:23:09,270 --> 00:23:06,080
the gout first seen by galileo goliath

540
00:23:11,110 --> 00:23:09,280
in this in the early part of the 1600s

541
00:23:13,190 --> 00:23:11,120
and what we're actually seeing when we

542
00:23:15,830 --> 00:23:13,200
see the different colors of jupiter is

543
00:23:17,909 --> 00:23:15,840
that at these different points we are

544
00:23:19,909 --> 00:23:17,919
seeing different depths

545
00:23:22,950 --> 00:23:19,919
into the cloud deck

546
00:23:25,350 --> 00:23:22,960
so the great red spot is a point where

547
00:23:27,430 --> 00:23:25,360
we're seeing all the way down into the

548
00:23:30,630 --> 00:23:27,440
ammonium hydrosulfide

549
00:23:32,470 --> 00:23:30,640
that is sh that is reflecting back red

550
00:23:34,870 --> 00:23:32,480
light

551
00:23:37,190 --> 00:23:34,880
so we have to know about what would the

552
00:23:39,510 --> 00:23:37,200
atmospheres of an exoplanet in the

553
00:23:42,149 --> 00:23:39,520
habitable zone likely be made of

554
00:23:46,390 --> 00:23:42,159
and how would that interact with light

555
00:23:49,510 --> 00:23:47,269
and

556
00:23:52,149 --> 00:23:49,520
this is i'd like to really acknowledge

557
00:23:54,230 --> 00:23:52,159
um cad komachek maryland he is a world

558
00:23:55,990 --> 00:23:54,240
expert in exoplanet atmospheres and

559
00:23:58,390 --> 00:23:56,000
helped me out a lot with the answer to

560
00:24:00,070 --> 00:23:58,400
this question which actually we don't

561
00:24:02,310 --> 00:24:00,080
really know yet

562
00:24:04,710 --> 00:24:02,320
these are this is work from looking at

563
00:24:06,549 --> 00:24:04,720

colors of hot jupiters and how they

564
00:24:08,950 --> 00:24:06,559
would look to the human eye so these are

565
00:24:12,470 --> 00:24:08,960
not in the habitable zone these are

566
00:24:14,789 --> 00:24:12,480
massive jupiter jupiter-sized gas giants

567
00:24:17,669 --> 00:24:14,799
or even more massive than jupiter that

568
00:24:19,269 --> 00:24:17,679
are orbiting inside the orbit of mercury

569
00:24:21,669 --> 00:24:19,279
in fact the atmospheres of some of these

570
00:24:23,830 --> 00:24:21,679
would be so hot that they would their

571
00:24:27,190 --> 00:24:23,840
atmospheres would be made of metals so

572
00:24:29,750 --> 00:24:27,200
this is magnesium for instance

573
00:24:31,669 --> 00:24:29,760
and while a few of these are red

574
00:24:33,350 --> 00:24:31,679
overwhelmingly they would not look red

575
00:24:36,149 --> 00:24:33,360
to the eye

576
00:24:36,950 --> 00:24:36,159
and i emailed dr komichek and i asked

577
00:24:39,669 --> 00:24:36,960
him

578
00:24:41,430 --> 00:24:39,679
what what did he think was was likely

579
00:24:42,870 --> 00:24:41,440
for the color of a planet in the

580
00:24:45,269 --> 00:24:42,880
habitable zone

581
00:24:47,909 --> 00:24:45,279
and the likely color of a gas giant in

582
00:24:50,390 --> 00:24:47,919
the habitable zone he said would be hazy

583
00:24:53,029 --> 00:24:50,400
a yellow orange haze

584
00:24:53,830 --> 00:24:53,039
similar to titan which you see here

585
00:24:55,510 --> 00:24:53,840
or

586
00:24:58,470 --> 00:24:55,520
saturn

587
00:25:00,470 --> 00:24:58,480
so unfortunately yavin prime likely

588
00:25:06,549 --> 00:25:00,480

wouldn't be red it would actually be

589
00:25:12,549 --> 00:25:10,230
second what's the size of yavin prime

590
00:25:15,269 --> 00:25:12,559
how big is the gas giant and i promise

591
00:25:17,590 --> 00:25:15,279
you because to figure out

592
00:25:21,750 --> 00:25:17,600
how orbital dynamics

593
00:25:23,909 --> 00:25:21,760
laws of orbital mechanics helped give

594
00:25:25,830 --> 00:25:23,919
the rebels just enough time to blow up

595
00:25:28,230 --> 00:25:25,840
the death star we need to learn

596
00:25:32,310 --> 00:25:28,240
something about the gas giant that yavin

597
00:25:37,510 --> 00:25:34,870
and to do that we need to actually learn

598
00:25:39,350 --> 00:25:37,520
something about the size of yavin 4. so

599
00:25:42,149 --> 00:25:39,360
we're going to make the first of many

600
00:25:44,789 --> 00:25:42,159
assumptions over the course of this talk

601
00:25:47,269 --> 00:25:44,799
and that is that the excellent is that

602
00:25:49,430 --> 00:25:47,279
since all the rebels on yavin 4 are

603
00:25:51,669 --> 00:25:49,440
walking around without too much trouble

604
00:25:54,549 --> 00:25:51,679
we're going to assume that the gravity

605
00:25:57,190 --> 00:25:54,559
on yavin 4 is very similar to gravity on

606
00:25:59,269 --> 00:25:57,200
an earth-like planet

607
00:26:01,510 --> 00:25:59,279
and the acceleration due to gravity on

608
00:26:03,029 --> 00:26:01,520
the surface of a planet depends on just

609
00:26:05,830 --> 00:26:03,039
two things

610
00:26:07,350 --> 00:26:05,840
how massive the planet is and how big

611
00:26:09,590 --> 00:26:07,360
the planet is

612
00:26:11,909 --> 00:26:09,600
a more massive planet of the same size

613
00:26:14,230 --> 00:26:11,919

will have a stronger acceleration due to

614
00:26:16,310 --> 00:26:14,240
gravity you would weigh more

615
00:26:18,149 --> 00:26:16,320
on that planet

616
00:26:20,630 --> 00:26:18,159
but if you take a planet with the same

617
00:26:22,950 --> 00:26:20,640
mass and you make it bigger

618
00:26:25,430 --> 00:26:22,960
the acceleration due to gravity would

619
00:26:26,710 --> 00:26:25,440
drop and you would weigh less on that

620
00:26:29,269 --> 00:26:26,720
planet

621
00:26:31,510 --> 00:26:29,279
so a good shorthand for this is that the

622
00:26:34,310 --> 00:26:31,520
acceleration due to gravity depends on

623
00:26:37,350 --> 00:26:34,320
the density of a planet so if two

624
00:26:39,430 --> 00:26:37,360
planets likely have the same density

625
00:26:42,070 --> 00:26:39,440
they will have the same acceleration due

626
00:26:48,230 --> 00:26:42,080
to gravity and the same mass and the

627
00:26:51,590 --> 00:26:50,549
so how so and so what you're looking at

628
00:26:54,390 --> 00:26:51,600
here

629
00:26:55,669 --> 00:26:54,400
is a subset of all of the planets that

630
00:26:57,909 --> 00:26:55,679
we have found

631
00:27:00,149 --> 00:26:57,919
using various methods but largely with

632
00:27:02,230 --> 00:27:00,159
the kepler spacecraft

633
00:27:05,990 --> 00:27:02,240
on coming across the bottom is the

634
00:27:07,590 --> 00:27:06,000
planetary mass in earth unit so one here

635
00:27:09,990 --> 00:27:07,600
is one earth

636
00:27:11,590 --> 00:27:10,000
10 earths and 100 earths

637
00:27:13,830 --> 00:27:11,600
and notice that this isn't a linear

638
00:27:15,990 --> 00:27:13,840

scale this is a log scale which

639
00:27:18,710 --> 00:27:16,000
astronomers actually use because we deal

640
00:27:21,190 --> 00:27:18,720
with huge ranges and numbers

641
00:27:24,070 --> 00:27:21,200
vertically you're looking at the size of

642
00:27:27,190 --> 00:27:24,080
the planet so this is one earth diameter

643
00:27:29,190 --> 00:27:27,200
versus 10 earth diameters

644
00:27:32,470 --> 00:27:29,200
and one thing to notice is that all the

645
00:27:35,350 --> 00:27:32,480
terrestrial planets that we are finding

646
00:27:38,149 --> 00:27:35,360
tend to have about the same density

647
00:27:40,389 --> 00:27:38,159
as the earth and venus

648
00:27:42,549 --> 00:27:40,399
and since we already said that yavin

649
00:27:44,950 --> 00:27:42,559
prime and yavin 4 formed in the

650
00:27:45,990 --> 00:27:44,960
habitable zone around their world

651
00:27:49,110 --> 00:27:46,000
which is

652
00:27:52,149 --> 00:27:49,120
about 1au out we can assume that that

653
00:27:53,909 --> 00:27:52,159
yavin 4 is made up of basically the same

654
00:27:56,389 --> 00:27:53,919
stuff as the earth

655
00:27:58,310 --> 00:27:56,399
so the size of yavin and we also know

656
00:27:59,590 --> 00:27:58,320
that it probably has the same surface

657
00:28:02,149 --> 00:27:59,600
gravity

658
00:28:03,190 --> 00:28:02,159
which means that it is about the same

659
00:28:05,830 --> 00:28:03,200
size

660
00:28:08,630 --> 00:28:05,840
so we now know

661
00:28:12,549 --> 00:28:08,640
that each of these circles

662
00:28:14,870 --> 00:28:12,559
is about is about the size of the earth

663
00:28:18,470 --> 00:28:14,880

so how can we use this to figure out the

664
00:28:22,230 --> 00:28:20,230
well i could have done this using

665
00:28:24,310 --> 00:28:22,240
complicated geometry angles and some

666
00:28:26,950 --> 00:28:24,320
very terrifying calculus but instead i

667
00:28:29,830 --> 00:28:26,960
drew circles in powerpoint

668
00:28:32,070 --> 00:28:29,840
so the big red circle is roughly the

669
00:28:33,990 --> 00:28:32,080
scale of yavin prime

670
00:28:37,430 --> 00:28:34,000
and then the green circle here

671
00:28:41,190 --> 00:28:37,440
represents the scale of yavin iv the

672
00:28:43,510 --> 00:28:41,200
moon in which the rebel base is occupied

673
00:28:45,590 --> 00:28:43,520
and the diameter and then i just look to

674
00:28:49,990 --> 00:28:45,600
see how many

675
00:28:53,190 --> 00:28:50,000
yavin 4's fit across yavin prime nothing

676
00:28:55,510 --> 00:28:53,200
fancy nothing up my sleeves

677
00:28:58,310 --> 00:28:55,520
and we and the diameter of yavin prime

678
00:29:00,549 --> 00:28:58,320
is about 8.5 times the diameter of yavin

679
00:29:02,230 --> 00:29:00,559
4 which is about and since we're

680
00:29:04,389 --> 00:29:02,240
assuming that

681
00:29:06,549 --> 00:29:04,399
yavin 4 is about the size of the earth

682
00:29:09,190 --> 00:29:06,559
that means that we have a gas giant

683
00:29:11,190 --> 00:29:09,200
that's about 8.5 times the diameter of

684
00:29:12,870 --> 00:29:11,200
the earth

685
00:29:14,310 --> 00:29:12,880
and this is actually

686
00:29:16,230 --> 00:29:14,320
in line

687
00:29:18,149 --> 00:29:16,240
with the size of the gas giants in our

688
00:29:22,149 --> 00:29:18,159

own solar system jupiter is a little

689
00:29:24,070 --> 00:29:22,159
over 10 times the radius of the earth

690
00:29:25,590 --> 00:29:24,080
uranus and neptune are more like about

691
00:29:27,909 --> 00:29:25,600
six times the radius of the earth so

692
00:29:29,909 --> 00:29:27,919
this isn't this is actually in line with

693
00:29:32,149 --> 00:29:29,919
that what we what that ratio would be in

694
00:29:33,990 --> 00:29:32,159
our solar system

695
00:29:36,789 --> 00:29:34,000
however as a moon

696
00:29:38,310 --> 00:29:36,799
ganymede the largest moon of jupiter

697
00:29:42,950 --> 00:29:38,320
is um

698
00:29:45,190 --> 00:29:42,960
jupiter is 26 times bigger than ganymede

699
00:29:47,269 --> 00:29:45,200
so you basically so

700
00:29:49,510 --> 00:29:47,279
whereas the earth moon system

701
00:29:51,190 --> 00:29:49,520
the earth is actually only four times

702
00:29:53,510 --> 00:29:51,200
bigger than the moon and our moon is

703
00:29:56,630 --> 00:29:53,520
very big compared to the earth actually

704
00:29:57,830 --> 00:29:56,640
bizarrely so

705
00:30:01,909 --> 00:29:57,840
so

706
00:30:05,190 --> 00:30:01,919
y'all what we can say is that the size

707
00:30:07,669 --> 00:30:05,200
of the size of yavin prime of the gas

708
00:30:09,190 --> 00:30:07,679
giant is in line with what we expect for

709
00:30:13,350 --> 00:30:09,200
gas giants

710
00:30:20,230 --> 00:30:13,360
even if yavin 4 is on the big side for a

711
00:30:25,710 --> 00:30:23,269
and when we compare this to what we know

712
00:30:28,230 --> 00:30:25,720
about not only our own solar system but

713
00:30:30,710 --> 00:30:28,240

exoplanetary systems around planetary

714
00:30:34,310 --> 00:30:30,720
systems orbiting other stars

715
00:30:36,389 --> 00:30:34,320
you see this red bar coming across here

716
00:30:40,070 --> 00:30:36,399
and so this is roughly equivalent to

717
00:30:44,470 --> 00:30:40,080
something the size of neptune or uranus

718
00:30:47,430 --> 00:30:44,480
or maybe even saturn but not not jupiter

719
00:30:50,070 --> 00:30:47,440
and not these super jupiters these super

720
00:30:53,029 --> 00:30:50,080
massive hot jupiters that were initially

721
00:30:55,510 --> 00:30:53,039
discovered orbiting very very close to

722
00:30:57,669 --> 00:30:55,520
their parent stars

723
00:31:00,149 --> 00:30:57,679
so and for and i want to remind you of

724
00:31:03,190 --> 00:31:00,159
something george lucas

725
00:31:05,509 --> 00:31:03,200
wrote these in the 1970s

726
00:31:08,470 --> 00:31:05,519
star wars episode 4

727
00:31:09,990 --> 00:31:08,480
premiered in 1979

728
00:31:11,750 --> 00:31:10,000
actually for those that i'm about to

729
00:31:15,190 --> 00:31:11,760
make a chunk of you feel very old that

730
00:31:17,909 --> 00:31:15,200
was several years before i was born

731
00:31:21,110 --> 00:31:17,919
but it was also 16 years before the

732
00:31:24,070 --> 00:31:21,120
discovery of 51 pegasi be the first

733
00:31:25,110 --> 00:31:24,080
extrasolar planet so george lucas

734
00:31:27,190 --> 00:31:25,120
had

735
00:31:29,669 --> 00:31:27,200
it was 16 years before we've even

736
00:31:31,430 --> 00:31:29,679
discovered any planets and other systems

737
00:31:35,430 --> 00:31:31,440
and so far

738
00:31:40,870 --> 00:31:37,909

so how do we determine the mass of yavin

739
00:31:42,789 --> 00:31:40,880
4 and what you all came for how does

740
00:31:44,830 --> 00:31:42,799
orbital mechanics explain the

741
00:31:46,789 --> 00:31:44,840
destruction of the death

742
00:31:48,070 --> 00:31:46,799
star so

743
00:31:51,269 --> 00:31:48,080
basically

744
00:31:52,950 --> 00:31:51,279
we're going so the so yavin 4 is nicely

745
00:31:55,190 --> 00:31:52,960
orbiting

746
00:31:56,870 --> 00:31:55,200
at the gas giant

747
00:31:59,590 --> 00:31:56,880
and the death star pops out of

748
00:32:03,669 --> 00:32:01,830
and why it pops out of hyperspace on the

749
00:32:05,750 --> 00:32:03,679
other side of the planet how you get

750
00:32:07,669 --> 00:32:05,760
something the size of us of a moon

751
00:32:11,110 --> 00:32:07,679
moving through hyperspace

752
00:32:12,310 --> 00:32:11,120
that's talk to george lucas on that one

753
00:32:14,789 --> 00:32:12,320
but

754
00:32:16,389 --> 00:32:14,799
the important thing is that it's that's

755
00:32:18,470 --> 00:32:16,399
not a moon

756
00:32:19,990 --> 00:32:18,480
that's a space station and that's that's

757
00:32:21,669 --> 00:32:20,000
the crux of this

758
00:32:24,870 --> 00:32:21,679
is probably again one of the most famous

759
00:32:27,509 --> 00:32:24,880
lines in um episode four is that's not a

760
00:32:29,830 --> 00:32:27,519
moon that's a space station

761
00:32:31,669 --> 00:32:29,840
the death star is effectively an

762
00:32:33,830 --> 00:32:31,679
orbiting body

763
00:32:35,430 --> 00:32:33,840

once it enters a system that means that

764
00:32:37,509 --> 00:32:35,440
it's not going to be able to just fire

765
00:32:39,590 --> 00:32:37,519
thrusters and move around once it's in

766
00:32:41,990 --> 00:32:39,600
the system it's going to have to obey

767
00:32:44,789 --> 00:32:42,000
the laws of orbital mechanics and go

768
00:32:47,430 --> 00:32:44,799
into orbit around either the sun of that

769
00:32:49,110 --> 00:32:47,440
system or around in this case the gas

770
00:32:50,630 --> 00:32:49,120
giant

771
00:32:52,070 --> 00:32:50,640
so the death star has tracked the

772
00:32:53,830 --> 00:32:52,080
millennium falcon it comes out of

773
00:32:58,230 --> 00:32:53,840
hyperspace it goes into orbit around

774
00:33:00,630 --> 00:32:58,240
yavin prime and now it's got a weight

775
00:33:03,269 --> 00:33:00,640
to orbit around the planet

776
00:33:04,389 --> 00:33:03,279
until the rebel base comes into

777
00:33:07,830 --> 00:33:04,399
targeting

778
00:33:13,590 --> 00:33:10,870
so how does this actually help us

779
00:33:15,909 --> 00:33:13,600
determine the mass of yavin 4 and

780
00:33:20,470 --> 00:33:15,919
actually this the targeting display on

781
00:33:29,909 --> 00:33:24,310
it takes 33 minutes for yavin 4 to go

782
00:33:36,710 --> 00:33:31,669
and so we now know

783
00:33:38,389 --> 00:33:36,720
how fast yavin 4 is going around

784
00:33:41,110 --> 00:33:38,399
the is going around

785
00:33:42,389 --> 00:33:41,120
the gas giant

786
00:33:44,710 --> 00:33:42,399
and

787
00:33:47,190 --> 00:33:44,720
if we know how fast yavin 4 is going

788
00:33:48,950 --> 00:33:47,200

around the gas giant and we know

789
00:33:52,870 --> 00:33:48,960
and we assume it's on a circular it and

790
00:33:55,269 --> 00:33:52,880
the death star or on circular orbits

791
00:33:59,110 --> 00:33:55,279
we can use this

792
00:34:06,389 --> 00:33:59,120
to figure out how massive

793
00:34:10,310 --> 00:34:08,149
and so the rebels they have their

794
00:34:12,710 --> 00:34:10,320
precious 30 minutes they go out we all

795
00:34:14,629 --> 00:34:12,720
know that you know we all know the story

796
00:34:18,149 --> 00:34:14,639
blows bloat they blow up the death star

797
00:34:20,550 --> 00:34:18,159
at the absolute last possible second

798
00:34:23,430 --> 00:34:20,560
but how massive would yavin prime the

799
00:34:24,389 --> 00:34:23,440
gas giant have to be to give them that

800
00:34:25,990 --> 00:34:24,399
time

801
00:34:29,669 --> 00:34:26,000
and is this number

802
00:34:32,790 --> 00:34:29,679
even close to reasonable

803
00:34:35,430 --> 00:34:32,800
so i made an assumption i said we have a

804
00:34:38,629 --> 00:34:35,440
large moon orbiting a gas giant

805
00:34:41,109 --> 00:34:38,639
and i figured it probably was somewhere

806
00:34:42,149 --> 00:34:41,119
at about the orbit about the same

807
00:34:46,149 --> 00:34:42,159
distance

808
00:34:48,310 --> 00:34:46,159
as ganymede is around jupiter

809
00:34:50,710 --> 00:34:48,320
so units making the assumption that in

810
00:34:53,430 --> 00:34:50,720
general planetary moon systems around

811
00:34:54,470 --> 00:34:53,440
gas giants would probably be relatively

812
00:35:00,150 --> 00:34:54,480
similar

813
00:35:02,550 --> 00:35:00,160

but again this isn't necessarily a safe

814
00:35:04,470 --> 00:35:02,560
assumption but it's the but the only

815
00:35:06,630 --> 00:35:04,480
massive gas giant with a large moon

816
00:35:09,030 --> 00:35:06,640
system that we have are the ones in our

817
00:35:11,270 --> 00:35:09,040
solar system

818
00:35:13,190 --> 00:35:11,280
and when we put all this together so we

819
00:35:14,390 --> 00:35:13,200
put the size of yavin 4 that we

820
00:35:17,109 --> 00:35:14,400
calculated

821
00:35:19,270 --> 00:35:17,119
we can we can measure from this how long

822
00:35:21,190 --> 00:35:19,280
it makes it around takes it to make it

823
00:35:23,270 --> 00:35:21,200
makes it around java force we know how

824
00:35:25,510 --> 00:35:23,280
fast it's going

825
00:35:27,510 --> 00:35:25,520
and we're making the assumption that

826
00:35:30,390 --> 00:35:27,520
it's a moon around a gas giant so it's

827
00:35:31,750 --> 00:35:30,400
probably about as far out as ganymede

828
00:35:35,589 --> 00:35:31,760
we get

829
00:35:39,589 --> 00:35:35,599
that yavin yavin prime the gas giant is

830
00:35:45,829 --> 00:35:42,870
and while that's a little massive

831
00:35:47,910 --> 00:35:45,839
it's not completely out of the realm of

832
00:35:48,870 --> 00:35:47,920
possibility

833
00:35:54,230 --> 00:35:48,880
so

834
00:35:57,030 --> 00:35:54,240
base orbiting

835
00:35:58,950 --> 00:35:57,040
a jupiter mass gas giant

836
00:36:01,349 --> 00:35:58,960
and the death star showed up on the

837
00:36:03,750 --> 00:36:01,359
wrong side of the planet

838
00:36:05,910 --> 00:36:03,760

and if you're orbiting that planet it's

839
00:36:08,390 --> 00:36:05,920
going to take you half an hour

840
00:36:09,829 --> 00:36:08,400
before you can blow it up

841
00:36:12,550 --> 00:36:09,839
and those are the laws of that's

842
00:36:15,829 --> 00:36:12,560
newtonian that's newtonian gravity

843
00:36:19,270 --> 00:36:15,839
combination of basic newtonian gravity

844
00:36:21,990 --> 00:36:19,280
and some very simple orbital mechanics

845
00:36:23,829 --> 00:36:22,000
and that's what gave them enough time

846
00:36:25,829 --> 00:36:23,839
but

847
00:36:29,589 --> 00:36:25,839
how did we get all this wonderful

848
00:36:35,510 --> 00:36:29,599
exoplanet data that i've been comparing

849
00:36:40,790 --> 00:36:37,910
so we have two options when it comes to

850
00:36:44,630 --> 00:36:40,800
detecting exoplanets and the first one

851
00:36:46,230 --> 00:36:44,640
is a stellar wobble or dot or looking at

852
00:36:48,069 --> 00:36:46,240
the doppler

853
00:36:49,750 --> 00:36:48,079
you've this is talked about cellular

854
00:36:51,990 --> 00:36:49,760
wobble it's mentioned that you're you're

855
00:36:54,550 --> 00:36:52,000
detecting the va

856
00:36:57,589 --> 00:36:54,560
doppler shifts but they're basically the

857
00:37:01,750 --> 00:36:59,670
and this was how we detected the very

858
00:37:03,829 --> 00:37:01,760
first exoplanets

859
00:37:05,990 --> 00:37:03,839
and how this works is that you have and

860
00:37:08,630 --> 00:37:06,000
i'm going to use an iphone and airpods

861
00:37:11,109 --> 00:37:08,640
to demonstrate this if i can

862
00:37:13,190 --> 00:37:11,119
so you have two systems

863
00:37:15,670 --> 00:37:13,200

you have two stars you could be a star

864
00:37:18,390 --> 00:37:15,680
and a planet it can be a gas giant in

865
00:37:20,150 --> 00:37:18,400
its moon but anytime you have two things

866
00:37:23,910 --> 00:37:20,160
orbiting each other

867
00:37:26,630 --> 00:37:23,920
one object doesn't orbit the other

868
00:37:29,109 --> 00:37:26,640
what they orbit around is a common

869
00:37:31,030 --> 00:37:29,119
center of mass

870
00:37:33,430 --> 00:37:31,040
if the two objects are equal mass the

871
00:37:35,190 --> 00:37:33,440
center of mass will be halfway

872
00:37:37,589 --> 00:37:35,200
between them

873
00:37:40,230 --> 00:37:37,599
if like the earth and the sun one object

874
00:37:41,030 --> 00:37:40,240
is significantly more massive than the

875
00:37:43,270 --> 00:37:41,040
other

876
00:37:45,190 --> 00:37:43,280
the center of mass will actually be very

877
00:37:46,950 --> 00:37:45,200
close to the center of the more massive

878
00:37:48,710 --> 00:37:46,960
objects so the center of mass for

879
00:37:50,790 --> 00:37:48,720
instance the earth's sun

880
00:37:53,190 --> 00:37:50,800
is actually very very close to the

881
00:37:56,069 --> 00:37:53,200
center of the sun

882
00:37:57,990 --> 00:37:56,079
but if you have a mass so so if you have

883
00:38:01,030 --> 00:37:58,000
a massive planet

884
00:38:02,870 --> 00:38:01,040
orbiting around its parent star

885
00:38:05,190 --> 00:38:02,880
the center of mass

886
00:38:08,950 --> 00:38:05,200
of the planet and the star is going to

887
00:38:11,190 --> 00:38:08,960
be ever so slightly outside the star

888
00:38:14,470 --> 00:38:11,200

so the star will actually be rotating

889
00:38:18,390 --> 00:38:14,480
around this center of mass

890
00:38:21,349 --> 00:38:18,400
and we detect this as a stellar wobble

891
00:38:28,230 --> 00:38:21,359
the more massive a planet is the larger

892
00:38:33,030 --> 00:38:30,390
and what happens is as the star is

893
00:38:35,190 --> 00:38:33,040
moving away from us its light is ever so

894
00:38:37,030 --> 00:38:35,200
slow spectral lines

895
00:38:38,790 --> 00:38:37,040
in its light are ever so slightly

896
00:38:40,390 --> 00:38:38,800
shifted to the red

897
00:38:42,390 --> 00:38:40,400
and then when it moves towards you again

898
00:38:44,790 --> 00:38:42,400
if they're ever so slightly shifted to

899
00:38:46,470 --> 00:38:44,800
shorter wavelengths to the blue

900
00:38:49,990 --> 00:38:46,480
and it does this

901
00:38:52,390 --> 00:38:50,000
with a very regular pattern so you see a

902
00:38:56,950 --> 00:38:52,400
period

903
00:38:58,950 --> 00:38:56,960
how long it's taking the star to go

904
00:39:01,030 --> 00:38:58,960
around the center of mass

905
00:39:04,950 --> 00:39:01,040
from the size of the shift you can

906
00:39:11,190 --> 00:39:08,069
and coupling all those things together

907
00:39:13,589 --> 00:39:11,200
the first planets that were discovered

908
00:39:15,270 --> 00:39:13,599
turned out to be nothing like our solar

909
00:39:18,870 --> 00:39:15,280
system

910
00:39:19,990 --> 00:39:18,880
51 pega cb was many times the mass of

911
00:39:23,109 --> 00:39:20,000
jupiter

912
00:39:24,750 --> 00:39:23,119
orbiting inside the orbit of mercury

913
00:39:27,430 --> 00:39:24,760

something that was

914
00:39:29,349 --> 00:39:27,440
inconceivable before the discovery of

915
00:39:31,910 --> 00:39:29,359
the first hot jupiters

916
00:39:32,790 --> 00:39:31,920
we've now found many of them

917
00:39:37,589 --> 00:39:32,800
and

918
00:39:40,790 --> 00:39:37,599
model of solar system formation

919
00:39:42,950 --> 00:39:40,800
that our solar system wasn't like every

920
00:39:45,349 --> 00:39:42,960
solar system in the galaxy that they

921
00:39:47,109 --> 00:39:45,359
were they were far more diverse and far

922
00:39:49,589 --> 00:39:47,119
more bizarre

923
00:39:51,349 --> 00:39:49,599
than we ever could have imagined

924
00:39:53,670 --> 00:39:51,359
but stellar wobble

925
00:39:56,710 --> 00:39:53,680
has a problem

926
00:39:57,910 --> 00:39:56,720
it's going to primarily detect massive

927
00:40:00,870 --> 00:39:57,920
planets

928
00:40:02,870 --> 00:40:00,880
on short periods so it has a bias it's

929
00:40:05,109 --> 00:40:02,880
good it's not going to give you a fair

930
00:40:08,870 --> 00:40:05,119
sample of all the exoplanets out there

931
00:40:10,870 --> 00:40:08,880
so we need another way to go about this

932
00:40:12,710 --> 00:40:10,880
and the other way we go about this is

933
00:40:14,870 --> 00:40:12,720
using transits

934
00:40:18,550 --> 00:40:14,880
and most many of our transits have been

935
00:40:21,270 --> 00:40:18,560
detected by the kepler spacecraft

936
00:40:23,349 --> 00:40:21,280
and the way transits work is very simple

937
00:40:25,670 --> 00:40:23,359
if any of you saw the transit of venus

938
00:40:27,750 --> 00:40:25,680

which i know was a long time ago

939
00:40:31,349 --> 00:40:27,760
how many if you saw the solar eclipse

940
00:40:33,349 --> 00:40:31,359
where the solar eclipse in 2017 in 2017

941
00:40:35,109 --> 00:40:33,359
where the moon moved

942
00:40:38,230 --> 00:40:35,119
in front of the sun

943
00:40:39,349 --> 00:40:38,240
transits work and effectively the same

944
00:40:42,069 --> 00:40:39,359
way

945
00:40:44,470 --> 00:40:42,079
we look out and there happens to be a

946
00:40:45,349 --> 00:40:44,480
planetary system

947
00:40:47,430 --> 00:40:45,359
where

948
00:40:50,470 --> 00:40:47,440
the planet

949
00:40:52,550 --> 00:40:50,480
comes directly between us

950
00:40:54,950 --> 00:40:52,560
and the star

951
00:40:59,589 --> 00:40:54,960
and when that happened the planet blocks

952
00:41:01,670 --> 00:40:59,599
a fraction of the light from the star

953
00:41:03,190 --> 00:41:01,680
and so it comes in it starts blocking

954
00:41:05,349 --> 00:41:03,200
the light from the star the light from

955
00:41:07,349 --> 00:41:05,359
the star drops

956
00:41:09,990 --> 00:41:07,359
the length of the transit is the amount

957
00:41:12,470 --> 00:41:10,000
of time it takes for the planet to

958
00:41:14,470 --> 00:41:12,480
transit across the star and then as it

959
00:41:18,309 --> 00:41:14,480
transits off the face of the star the

960
00:41:20,550 --> 00:41:18,319
star returns to its normal brightness

961
00:41:22,470 --> 00:41:20,560
and from this you can determine many

962
00:41:24,710 --> 00:41:22,480
things the characteristics of the

963
00:41:27,030 --> 00:41:24,720

atmosphere of the exoplanet

964
00:41:30,150 --> 00:41:27,040
and from how long it takes to go into

965
00:41:35,430 --> 00:41:30,160
full transit you can get the object's

966
00:41:40,309 --> 00:41:38,150
so as it's coming into transit

967
00:41:43,349 --> 00:41:40,319
you begin to drop and the larger the

968
00:41:45,349 --> 00:41:43,359
exoplanet the longer it will take to go

969
00:41:47,990 --> 00:41:45,359
into full eclipse

970
00:41:49,109 --> 00:41:48,000
the advantage of transits is that

971
00:41:50,870 --> 00:41:49,119
they're not

972
00:41:53,750 --> 00:41:50,880
biased as

973
00:41:56,710 --> 00:41:53,760
towards only these massive planets close

974
00:41:58,950 --> 00:41:56,720
into their stars and give us a far more

975
00:42:00,069 --> 00:41:58,960
representative sample

976
00:42:04,470 --> 00:42:00,079
of

977
00:42:05,510 --> 00:42:04,480
and the better telescope you have and

978
00:42:07,910 --> 00:42:05,520
the

979
00:42:10,150 --> 00:42:07,920
more accurate of a light curve you can

980
00:42:12,150 --> 00:42:10,160
get during those transits

981
00:42:14,550 --> 00:42:12,160
the better the data and the better the

982
00:42:16,069 --> 00:42:14,560
properties of the of these exoplanets

983
00:42:18,470 --> 00:42:16,079
that we can learn and this is one of the

984
00:42:21,670 --> 00:42:18,480
things that's going to be amazing with

985
00:42:28,150 --> 00:42:24,230
so what have we found

986
00:42:32,710 --> 00:42:28,160
there have been 5 000 plus planets found

987
00:42:35,589 --> 00:42:32,720
and confirmed about 30 or gas giants the

988
00:42:39,030 --> 00:42:35,599

size of saturn or jupiter

989
00:42:39,910 --> 00:42:39,040
some of them are big some of them can be

990
00:42:45,589 --> 00:42:39,920
10

991
00:42:47,190 --> 00:42:45,599
some of these hot jupiters that are

992
00:42:49,030 --> 00:42:47,200
orbiting close into their parent star

993
00:42:50,950 --> 00:42:49,040
can even be hotter than the surface of

994
00:42:53,109 --> 00:42:50,960
some stars

995
00:42:55,430 --> 00:42:53,119
so hot that their atmospheres are made

996
00:42:58,630 --> 00:42:55,440
of metal

997
00:43:01,510 --> 00:42:58,640
about 35 of the planets are neptune-like

998
00:43:03,510 --> 00:43:01,520
planets about the size of neptune and

999
00:43:05,589 --> 00:43:03,520
uranus

1000
00:43:08,230 --> 00:43:05,599
they can be ice giants

1001
00:43:10,150 --> 00:43:08,240
like the net like like the outer planets

1002
00:43:14,309 --> 00:43:10,160
in our solar system

1003
00:43:15,910 --> 00:43:14,319
but some of them can actually be warm

1004
00:43:18,309 --> 00:43:15,920
can actual or further into their start

1005
00:43:20,710 --> 00:43:18,319
it can actually be warm neptunes

1006
00:43:23,030 --> 00:43:20,720
about 31 of our plant of the planets

1007
00:43:25,030 --> 00:43:23,040
that we find are super earths

1008
00:43:27,109 --> 00:43:25,040
so these are planets that don't exist in

1009
00:43:28,950 --> 00:43:27,119
our solar system these these are several

1010
00:43:31,910 --> 00:43:28,960
times the mass of the earth somewhere

1011
00:43:33,750 --> 00:43:31,920
between earth and neptune so this is

1012
00:43:35,670 --> 00:43:33,760
actually a class of planets that we

1013
00:43:39,030 --> 00:43:35,680

can't study in our own solar system we

1014
00:43:47,670 --> 00:43:39,040
have to study them around other stars

1015
00:43:51,430 --> 00:43:49,589
and so what have we found

1016
00:43:53,430 --> 00:43:51,440
and the best way to describe this and

1017
00:43:55,510 --> 00:43:53,440
when i when i introduced this to intro

1018
00:43:57,030 --> 00:43:55,520
to astronomy students i tell them there

1019
00:43:58,950 --> 00:43:57,040
are more things in heaven and earth

1020
00:44:00,470 --> 00:43:58,960
horatio that are dreamt of in your

1021
00:44:02,230 --> 00:44:00,480
philosophy

1022
00:44:05,589 --> 00:44:02,240
or to put this in the parlance of

1023
00:44:08,230 --> 00:44:05,599
science fiction however weird whatever

1024
00:44:10,870 --> 00:44:08,240
weird concoctions humans have come up in

1025
00:44:17,270 --> 00:44:10,880
their imagination for planets i promise

1026
00:44:20,870 --> 00:44:19,109
so let's start with some ones that are

1027
00:44:22,790 --> 00:44:20,880
going to sound somewhat familiar if

1028
00:44:25,270 --> 00:44:22,800
you're a star wars fan so we're going to

1029
00:44:29,109 --> 00:44:25,280
start with 55 cans

1030
00:44:31,190 --> 00:44:29,119
cancer i e which is the 55 55th

1031
00:44:32,230 --> 00:44:31,200
brightest star in the constellation of

1032
00:44:38,069 --> 00:44:32,240
cancer

1033
00:44:42,470 --> 00:44:40,710
otherwise colloquially known as the lava

1034
00:44:45,430 --> 00:44:42,480
planet

1035
00:44:47,109 --> 00:44:45,440
this is an artist's impression of 55

1036
00:44:49,910 --> 00:44:47,119
cancery e

1037
00:44:53,190 --> 00:44:49,920
the surface of the planet is so hot but

1038
00:44:54,870 --> 00:44:53,200

it is a terrestrial world and the only

1039
00:44:57,910 --> 00:44:54,880
way that you can explain those two

1040
00:45:01,910 --> 00:44:57,920
things is if a significant fraction of

1041
00:45:05,190 --> 00:45:01,920
the planet is covered in lava so this is

1042
00:45:10,150 --> 00:45:05,200
an actual lava world that exists in our

1043
00:45:14,910 --> 00:45:12,150
then we have um

1044
00:45:17,750 --> 00:45:14,920
olga 2016 blg

1045
00:45:20,470 --> 00:45:17,760
195lb this is what happens when you have

1046
00:45:22,150 --> 00:45:20,480
a very faint star we don't actually name

1047
00:45:24,309 --> 00:45:22,160
it we give it what is colloquially

1048
00:45:27,030 --> 00:45:24,319
referred to as a phone number

1049
00:45:29,270 --> 00:45:27,040
but this is the second object orbiting

1050
00:45:33,030 --> 00:45:29,280
this this is the first planet orbiting

1051
00:45:35,510 --> 00:45:33,040
this star and it is an ice cold earth

1052
00:45:36,630 --> 00:45:35,520
orbiting a tiny star so it's the mass of

1053
00:45:39,750 --> 00:45:36,640
the earth

1054
00:45:43,109 --> 00:45:39,760
but it's orbiting so far from its low

1055
00:45:45,430 --> 00:45:43,119
mass parent star that it's frozen

1056
00:45:47,270 --> 00:45:45,440
completely solid

1057
00:45:49,910 --> 00:45:47,280
and when this came out everybody had a

1058
00:45:51,510 --> 00:45:49,920
lot of fun basically saying that have we

1059
00:45:53,349 --> 00:45:51,520
found hoth

1060
00:45:55,030 --> 00:45:53,359
um which people may remember is the

1061
00:45:57,030 --> 00:45:55,040
rebel base at the beginning of the

1062
00:45:59,190 --> 00:45:57,040
empire strikes back

1063
00:46:00,950 --> 00:45:59,200

but if you remember on hoth even though

1064
00:46:04,069 --> 00:46:00,960
everybody had to be in winter gear when

1065
00:46:06,069 --> 00:46:04,079
they were outside this planet is even

1066
00:46:06,870 --> 00:46:06,079
less hospitable

1067
00:46:08,470 --> 00:46:06,880
it's

1068
00:46:12,870 --> 00:46:08,480
temperatures are probably closer to

1069
00:46:14,470 --> 00:46:12,880
those of pluto in our own solar system

1070
00:46:15,270 --> 00:46:14,480
so ice worlds

1071
00:46:16,230 --> 00:46:15,280
check

1072
00:46:19,910 --> 00:46:16,240
easy

1073
00:46:25,670 --> 00:46:23,030
finally we have kepler-16b which has

1074
00:46:29,910 --> 00:46:25,680
actually been nicknamed tatooine

1075
00:46:32,470 --> 00:46:29,920
it is a planet that has two suns

1076
00:46:34,230 --> 00:46:32,480
this is one of the awesome nasa travel

1077
00:46:36,309 --> 00:46:34,240
posters that have been done for some of

1078
00:46:38,230 --> 00:46:36,319
our of the exoplanets if you want to

1079
00:46:40,230 --> 00:46:38,240
they are actually free to download and

1080
00:46:43,190 --> 00:46:40,240
print off of the

1081
00:46:45,270 --> 00:46:43,200
nasa website um they're absolutely all

1082
00:46:46,630 --> 00:46:45,280
spectacular kind of with an art deco

1083
00:46:50,230 --> 00:46:46,640
look to them

1084
00:46:52,390 --> 00:46:50,240
and this is that one for kepler-16b so

1085
00:46:55,670 --> 00:46:52,400
you're on the surface of the planet

1086
00:46:57,270 --> 00:46:55,680
and you're in the shadow of two suns

1087
00:47:03,510 --> 00:46:57,280
one of which

1088
00:47:05,990 --> 00:47:03,520

more massive and therefore a little more

1089
00:47:08,230 --> 00:47:06,000
orange yellow

1090
00:47:11,510 --> 00:47:08,240
and why is this

1091
00:47:14,470 --> 00:47:11,520
phenomenal why is this strange

1092
00:47:17,030 --> 00:47:14,480
in order for a planet to stably orbit a

1093
00:47:20,230 --> 00:47:17,040
binary system it likely has to orbit

1094
00:47:23,430 --> 00:47:20,240
outside of both stars

1095
00:47:26,549 --> 00:47:23,440
if a planet is trying to orbit or orbit

1096
00:47:29,990 --> 00:47:26,559
very very close to one star with the

1097
00:47:33,270 --> 00:47:30,000
second binary far away

1098
00:47:35,910 --> 00:47:33,280
so this is one this is one possibility

1099
00:47:39,750 --> 00:47:35,920
for a stable configuration

1100
00:47:42,710 --> 00:47:39,760
for a planet orbiting a binary star

1101
00:47:45,589 --> 00:47:42,720
also it's a beautiful example of how

1102
00:47:47,990 --> 00:47:45,599
science fiction about how astronomy both

1103
00:47:52,309 --> 00:47:48,000
feet both inform science fiction but

1104
00:47:54,870 --> 00:47:52,319
also feeds from science fiction um as um

1105
00:47:56,390 --> 00:47:54,880
as frank as dr summers said as we were

1106
00:47:59,349 --> 00:47:56,400
sort of prepping for this pretty much

1107
00:48:01,190 --> 00:47:59,359
for all we are generally all nerds

1108
00:48:02,950 --> 00:48:01,200
in fact there was there has been some

1109
00:48:04,950 --> 00:48:02,960
joking

1110
00:48:06,710 --> 00:48:04,960
sort of said that if we find terrestrial

1111
00:48:08,790 --> 00:48:06,720
planets in the habitable zone should we

1112
00:48:12,790 --> 00:48:08,800
call them m-class

1113
00:48:17,030 --> 00:48:15,190

and now we get to the weird

1114
00:48:18,790 --> 00:48:17,040
so those are three planets that should

1115
00:48:20,950 --> 00:48:18,800
seem somewhat familiar to you if you're

1116
00:48:23,190 --> 00:48:20,960
familiar with the star wars universe and

1117
00:48:26,230 --> 00:48:23,200
we found the things like them we found a

1118
00:48:28,150 --> 00:48:26,240
lava planet we found a planet orbiting a

1119
00:48:30,309 --> 00:48:28,160
binary star we found an ice a

1120
00:48:35,150 --> 00:48:30,319
terrestrial ice world

1121
00:48:40,549 --> 00:48:38,390
gj1214b is a mini neptune so it's a

1122
00:48:42,230 --> 00:48:40,559
neptune-like planet but it's less

1123
00:48:44,309 --> 00:48:42,240
massive than neptune

1124
00:48:49,829 --> 00:48:44,319
so here's the mass of neptune

1125
00:48:53,670 --> 00:48:51,750
and it's covered

1126
00:48:56,790 --> 00:48:53,680
in water

1127
00:48:58,710 --> 00:48:56,800
with salt clouds

1128
00:49:00,710 --> 00:48:58,720
an entire planet

1129
00:49:08,069 --> 00:49:00,720
covered in water

1130
00:49:12,309 --> 00:49:09,630
gj

1131
00:49:13,589 --> 00:49:12,319
347db we have got to come up with better

1132
00:49:17,030 --> 00:49:13,599
names for these

1133
00:49:19,270 --> 00:49:17,040
is actually a rapidly evaporating super

1134
00:49:21,109 --> 00:49:19,280
earth and this gets back to part of that

1135
00:49:23,829 --> 00:49:21,119
question of why don't we have really

1136
00:49:25,589 --> 00:49:23,839
warm neptunes

1137
00:49:28,630 --> 00:49:25,599
and the answer is

1138
00:49:31,030 --> 00:49:28,640

that if you get too close into your star

1139
00:49:36,710 --> 00:49:31,040
you get hot

1140
00:49:38,950 --> 00:49:36,720
and helium in the atmosphere gets hot

1141
00:49:40,950 --> 00:49:38,960
and when it gets hot all those atoms

1142
00:49:43,829 --> 00:49:40,960
start moving faster and faster and

1143
00:49:47,510 --> 00:49:43,839
faster until they're moving so fast they

1144
00:49:49,910 --> 00:49:47,520
can escape the gravity of the planet

1145
00:49:52,630 --> 00:49:49,920
so neptunes

1146
00:49:56,069 --> 00:49:52,640
can't be warmer than a certain amount

1147
00:49:58,630 --> 00:49:56,079
because they'll lose their atmospheres

1148
00:50:00,790 --> 00:49:58,640
and this particular planet is orbiting

1149
00:50:05,030 --> 00:50:00,800
so close to its parent star that its

1150
00:50:09,270 --> 00:50:07,349
and within a few billion years half the

1151
00:50:14,069 --> 00:50:09,280
planet's just going to be gone will have

1152
00:50:18,870 --> 00:50:17,270
finally we have trappist-1

1153
00:50:21,990 --> 00:50:18,880
it's a seven

1154
00:50:22,710 --> 00:50:22,000
tightly packed rocky planets orbiting an

1155
00:50:24,630 --> 00:50:22,720
m

1156
00:50:26,790 --> 00:50:24,640
dwarf

1157
00:50:30,470 --> 00:50:26,800
and it showed

1158
00:50:33,750 --> 00:50:30,480
that if you have seven planets

1159
00:50:37,190 --> 00:50:33,760
you can actually have seven planets

1160
00:50:40,790 --> 00:50:37,200
orbiting that tightly together

1161
00:50:43,109 --> 00:50:40,800
around a star in stable orbits

1162
00:50:45,030 --> 00:50:43,119
which we didn't know could happen before

1163
00:50:46,950 --> 00:50:45,040

trappist-1

1164
00:50:49,270 --> 00:50:46,960
however because it's they are orbiting

1165
00:50:50,870 --> 00:50:49,280
an m dwarf even though some of them are

1166
00:50:53,910 --> 00:50:50,880
in the habitable zone they are also

1167
00:50:56,230 --> 00:50:53,920
getting irradiated by those solar flares

1168
00:50:59,270 --> 00:50:56,240
and so it's unknown whether or not there

1169
00:51:02,309 --> 00:50:59,280
would actually be life on these worlds

1170
00:51:03,829 --> 00:51:02,319
so again based on what we've seen what

1171
00:51:08,710 --> 00:51:03,839
we've already found so far out there

1172
00:51:09,510 --> 00:51:08,720
with exoplanets i'm not counting it out

1173
00:51:11,109 --> 00:51:09,520
so

1174
00:51:13,109 --> 00:51:11,119
where do we stand

1175
00:51:15,349 --> 00:51:13,119
we stand on the cusp of science with

1176
00:51:17,109 --> 00:51:15,359
jwst

1177
00:51:19,670 --> 00:51:17,119
i mean in a week we are going to see the

1178
00:51:22,630 --> 00:51:19,680
first images that come down from it

1179
00:51:24,150 --> 00:51:22,640
we know of 5 000 exoplanets with more

1180
00:51:25,990 --> 00:51:24,160
confirmed

1181
00:51:28,630 --> 00:51:26,000
constantly

1182
00:51:31,349 --> 00:51:28,640
these planets are stranger and more

1183
00:51:33,270 --> 00:51:31,359
varied than anything science or science

1184
00:51:35,589 --> 00:51:33,280
fiction has imagined

1185
00:51:37,589 --> 00:51:35,599
so if you're watching this and you're

1186
00:51:39,589 --> 00:51:37,599
thinking about maybe starting your own

1187
00:51:41,990 --> 00:51:39,599
starting playing around with your own

1188
00:51:44,710 --> 00:51:42,000

science fiction universe

1189
00:51:46,549 --> 00:51:44,720
my advice would be go to the at

1190
00:51:48,630 --> 00:51:46,559
exoplanet archive

1191
00:51:50,390 --> 00:51:48,640
look to see what we've already found

1192
00:51:52,069 --> 00:51:50,400
because i promise you it will be

1193
00:51:54,069 --> 00:51:52,079
stranger

1194
00:51:56,630 --> 00:51:54,079
more varied and more incredible than

1195
00:51:59,190 --> 00:51:56,640
anything you could dream up

1196
00:52:01,589 --> 00:51:59,200
oh and the rebel alliance had plenty of

1197
00:52:02,829 --> 00:52:01,599
time to destroy the death star thanks to

1198
00:52:10,309 --> 00:52:02,839
orbital

1199
00:52:14,950 --> 00:52:12,630
thank you very much mia may the force be

1200
00:52:18,309 --> 00:52:14,960
with you and um

1201
00:52:20,309 --> 00:52:18,319
also with our our online audience uh

1202
00:52:22,630 --> 00:52:20,319
putting the questions in the chat

1203
00:52:24,230 --> 00:52:22,640
if you have questions for mia now's the

1204
00:52:26,549 --> 00:52:24,240
time to enter them in the chat and we

1205
00:52:28,710 --> 00:52:26,559
will ask them of her

1206
00:52:30,790 --> 00:52:28,720
but i as the host always get the chance

1207
00:52:35,030 --> 00:52:30,800
to ask the first question

1208
00:52:37,510 --> 00:52:35,040
um and so somebody was wondering um

1209
00:52:40,470 --> 00:52:37,520
how do we know star wars humanoids

1210
00:52:44,309 --> 00:52:40,480
breathe oxygen um and if they didn't

1211
00:52:49,270 --> 00:52:46,390
how does this change the analysis i mean

1212
00:52:51,589 --> 00:52:49,280
is this is does it uh make everything uh

1213
00:52:54,150 --> 00:52:51,599

uh null and void or

1214
00:52:55,670 --> 00:52:54,160
uh is it something that uh you haven't

1215
00:52:57,990 --> 00:52:55,680
considered yet here

1216
00:53:03,510 --> 00:53:01,910
well i am assuming that thanks frank um

1217
00:53:04,870 --> 00:53:03,520
i am assuming

1218
00:53:07,190 --> 00:53:04,880
for starters

1219
00:53:09,349 --> 00:53:07,200
we are some we are always basing

1220
00:53:11,030 --> 00:53:09,359
whenever we sort of do science fiction

1221
00:53:11,990 --> 00:53:11,040
we always do some internet based off of

1222
00:53:14,069 --> 00:53:12,000
ourselves

1223
00:53:16,069 --> 00:53:14,079
um particularly science fiction shows

1224
00:53:17,670 --> 00:53:16,079
particularly something made in the 1970s

1225
00:53:19,109 --> 00:53:17,680
and 80s before the advent of modern

1226
00:53:21,190 --> 00:53:19,119
special effects

1227
00:53:22,470 --> 00:53:21,200
um

1228
00:53:24,950 --> 00:53:22,480
so

1229
00:53:27,990 --> 00:53:24,960
i think it's fair given that there are

1230
00:53:30,230 --> 00:53:28,000
humans and they are called humans in

1231
00:53:33,829 --> 00:53:30,240
star wars that i am assuming that they

1232
00:53:34,870 --> 00:53:33,839
are biologically similar to humans on

1233
00:53:36,309 --> 00:53:34,880
earth

1234
00:53:38,790 --> 00:53:36,319
you would still be breathing in some

1235
00:53:42,390 --> 00:53:38,800
sort of reactive so all all

1236
00:53:43,430 --> 00:53:42,400
bodies everywhere take in something

1237
00:53:45,670 --> 00:53:43,440
use it

1238
00:53:47,430 --> 00:53:45,680

biologically to do what they need to do

1239
00:53:49,349 --> 00:53:47,440
and then expel a waste product in our

1240
00:53:53,109 --> 00:53:49,359
case we breathe in oxygen and we expel

1241
00:53:54,069 --> 00:53:53,119
co2 plants take in co2 and expel oxygen

1242
00:53:56,150 --> 00:53:54,079
so

1243
00:53:57,190 --> 00:53:56,160
if there if there is if it isn't o2 that

1244
00:53:58,950 --> 00:53:57,200
you're looking for you're still going to

1245
00:54:01,190 --> 00:53:58,960
be looking for some sort of reactive

1246
00:54:03,990 --> 00:54:01,200
signature of life that would only be

1247
00:54:05,030 --> 00:54:04,000
there in our galaxy because we know that

1248
00:54:07,829 --> 00:54:05,040
o2

1249
00:54:10,630 --> 00:54:07,839
yeah but yeah so that that's

1250
00:54:12,870 --> 00:54:10,640
given the less vegetation on yavin 4

1251
00:54:17,030 --> 00:54:12,880
right i mean yeah i'm assuming it had a

1252
00:54:21,910 --> 00:54:20,069
unless for some reason um

1253
00:54:23,510 --> 00:54:21,920
for some reason processes work

1254
00:54:24,870 --> 00:54:23,520
differently there

1255
00:54:26,870 --> 00:54:24,880
yeah for some reason maybe they have

1256
00:54:27,829 --> 00:54:26,880
reversed photosynthesis or something

1257
00:54:29,430 --> 00:54:27,839
yeah

1258
00:54:31,829 --> 00:54:29,440
but but i think i think

1259
00:54:34,150 --> 00:54:31,839
we already again like we have we assume

1260
00:54:37,829 --> 00:54:34,160
also like i i am kind of you know they

1261
00:54:38,710 --> 00:54:37,839
they did film that in decal

1262
00:54:41,030 --> 00:54:38,720
you know

1263
00:54:43,180 --> 00:54:41,040

i happen to know those trees were

1264
00:54:45,589 --> 00:54:43,190
producing photosynthesis

1265
00:54:47,829 --> 00:54:45,599
[Laughter]

1266
00:54:49,750 --> 00:54:47,839
all right so that was one of one of the

1267
00:54:53,109 --> 00:54:49,760
weirder questions there are other

1268
00:54:54,630 --> 00:54:53,119
questions uh grant uh justice have been

1269
00:54:56,789 --> 00:54:54,640
following them a little more closely

1270
00:54:59,109 --> 00:54:56,799
than i have so grant you want to turn on

1271
00:55:00,870 --> 00:54:59,119
your video and join us and uh

1272
00:55:02,789 --> 00:55:00,880
pull out the ques give us the questions

1273
00:55:04,150 --> 00:55:02,799
that you pulled out of the chat

1274
00:55:06,870 --> 00:55:04,160
and by the way for anybody who's

1275
00:55:10,870 --> 00:55:06,880
wondered yes i did math

1276
00:55:15,990 --> 00:55:13,829
so this is actually related to that um

1277
00:55:18,870 --> 00:55:16,000
can you expand a little bit more on how

1278
00:55:20,789 --> 00:55:18,880
you determine the mass of an object by

1279
00:55:23,270 --> 00:55:20,799
its transit

1280
00:55:26,870 --> 00:55:23,280
so the mass oftentimes when they do the

1281
00:55:28,630 --> 00:55:26,880
masses they do follow up with doppler

1282
00:55:32,150 --> 00:55:28,640
so once we know where the planet is we

1283
00:55:35,270 --> 00:55:32,160
can then target that system and do

1284
00:55:37,030 --> 00:55:35,280
sort of and do a doppler measurement so

1285
00:55:38,630 --> 00:55:37,040
you can't get a mass from transit you

1286
00:55:40,789 --> 00:55:38,640
would have to go back

1287
00:55:42,309 --> 00:55:40,799
but a transit you can just survey the

1288
00:55:44,630 --> 00:55:42,319

whole sky and look for the dip in

1289
00:55:46,470 --> 00:55:44,640
brightness so you can figure out where

1290
00:55:48,870 --> 00:55:46,480
exoplanets are for a huge number of

1291
00:55:50,789 --> 00:55:48,880
systems very very quickly

1292
00:55:53,270 --> 00:55:50,799
and whereas getting that doppler

1293
00:55:55,750 --> 00:55:53,280
measurement takes a lot more time you

1294
00:55:56,710 --> 00:55:55,760
have to actually get the spectra of the

1295
00:56:00,390 --> 00:55:56,720
star

1296
00:56:05,349 --> 00:56:01,190
so

1297
00:56:08,390 --> 00:56:05,359
that's why we say there's about five

1298
00:56:10,309 --> 00:56:08,400
thousand confirmed exoplanets we have

1299
00:56:12,069 --> 00:56:10,319
even more that are candidates

1300
00:56:14,789 --> 00:56:12,079
that are waiting for that follow-up to

1301
00:56:17,190 --> 00:56:14,799
confirm that yes what's causing that dip

1302
00:56:19,589 --> 00:56:17,200
in brightness is a planet orbiting the

1303
00:56:23,670 --> 00:56:21,910
all right but again this is not my area

1304
00:56:25,030 --> 00:56:23,680
of expertise so

1305
00:56:27,510 --> 00:56:25,040
um

1306
00:56:29,430 --> 00:56:27,520
there are i always feel sorry

1307
00:56:31,430 --> 00:56:29,440
i mean it it's it's basic basics you

1308
00:56:33,349 --> 00:56:31,440
know if you just have the the small

1309
00:56:35,510 --> 00:56:33,359
little thing blocking the light you know

1310
00:56:37,750 --> 00:56:35,520
you just you get the geometry of of the

1311
00:56:39,670 --> 00:56:37,760
the two things but if you don't know how

1312
00:56:41,589 --> 00:56:39,680
far away it is you don't actually have

1313
00:56:44,069 --> 00:56:41,599

have the full orbit for it and such so

1314
00:56:46,950 --> 00:56:44,079
and so you know you just but now you can

1315
00:56:49,430 --> 00:56:46,960
go back and do targeted observations

1316
00:56:50,069 --> 00:56:49,440
and you get and see the stellar because

1317
00:56:54,230 --> 00:56:50,079
the

1318
00:56:56,710 --> 00:56:54,240
which is dependent upon mass

1319
00:56:58,549 --> 00:56:56,720
so one is really dependent upon size one

1320
00:57:00,069 --> 00:56:58,559
is really dependent upon mass put the

1321
00:57:01,589 --> 00:57:00,079
two together you got the full

1322
00:57:03,910 --> 00:57:01,599
information on the system

1323
00:57:05,270 --> 00:57:03,920
exactly and what's in what's incredible

1324
00:57:07,349 --> 00:57:05,280
to me is that we can actually get

1325
00:57:09,109 --> 00:57:07,359
observed information on the atmosphere

1326
00:57:10,950 --> 00:57:09,119
of the system as it moves in and out of

1327
00:57:13,349 --> 00:57:10,960
transit like that

1328
00:57:14,710 --> 00:57:13,359
that to me i've had people explain to me

1329
00:57:17,030 --> 00:57:14,720
how it's done and it still feels a

1330
00:57:20,470 --> 00:57:17,040
little bit like black magic because it's

1331
00:57:23,190 --> 00:57:20,480
just so insane to me that you can get as

1332
00:57:25,270 --> 00:57:23,200
as it moves into and out of transit you

1333
00:57:26,630 --> 00:57:25,280
can actually like get information you're

1334
00:57:28,549 --> 00:57:26,640
looking at the star through the

1335
00:57:30,309 --> 00:57:28,559
atmosphere of the exoplanet and that

1336
00:57:31,990 --> 00:57:30,319
just

1337
00:57:34,870 --> 00:57:32,000
you know that's one of those like even

1338
00:57:37,349 --> 00:57:34,880

astronomer mind blow

1339
00:57:39,430 --> 00:57:37,359
mind blown moments i mean we are looking

1340
00:57:41,829 --> 00:57:39,440
at the atmosphere of a planet that we

1341
00:57:43,589 --> 00:57:41,839
can't see

1342
00:57:45,750 --> 00:57:43,599
we can detect what's in its atmosphere

1343
00:57:47,990 --> 00:57:45,760
but we can't actually see it yeah like

1344
00:57:49,829 --> 00:57:48,000
how we determine how how we find life

1345
00:57:52,230 --> 00:57:49,839
for the first time in the universe

1346
00:57:54,390 --> 00:57:52,240
is not going to be et phone home it's

1347
00:57:57,190 --> 00:57:54,400
going to be oh my god we have a clear

1348
00:57:58,150 --> 00:57:57,200
oxygen 2 signature in an exoplanet

1349
00:57:59,910 --> 00:57:58,160
atmosphere and then you're going to

1350
00:58:02,710 --> 00:57:59,920
watch like all of astrophysics go

1351
00:58:04,950 --> 00:58:02,720
completely insane okay all right but but

1352
00:58:08,069 --> 00:58:04,960
you know one one of our readers one of

1353
00:58:10,150 --> 00:58:08,079
our viewers actually sorry um brought up

1354
00:58:13,670 --> 00:58:10,160
that uh oxygen can also be produced

1355
00:58:15,349 --> 00:58:13,680
abiotically um so i mean on yavin iv

1356
00:58:16,870 --> 00:58:15,359
there was so much vegetation of course

1357
00:58:18,390 --> 00:58:16,880
the oxygen had to be produced from the

1358
00:58:20,150 --> 00:58:18,400
vegetation

1359
00:58:23,349 --> 00:58:20,160
if you saw it would be produced by

1360
00:58:25,430 --> 00:58:23,359
vegetation but could we in it i don't

1361
00:58:27,670 --> 00:58:25,440
know i don't i'm not an expert in this

1362
00:58:29,430 --> 00:58:27,680
either uh is there are there abiotic

1363
00:58:32,230 --> 00:58:29,440

processes that could produce enough

1364
00:58:36,309 --> 00:58:32,240
oxygen that you could get that signature

1365
00:58:38,470 --> 00:58:36,319
in an an atmosphere i don't know my

1366
00:58:40,390 --> 00:58:38,480
memory from when i learned about this my

1367
00:58:42,069 --> 00:58:40,400
memory from when i remember learning

1368
00:58:44,230 --> 00:58:42,079
about this when people sort of talk

1369
00:58:45,430 --> 00:58:44,240
we're talking about it was

1370
00:58:50,549 --> 00:58:45,440
no

1371
00:58:52,710 --> 00:58:50,559
and that if you want to get really high

1372
00:58:54,549 --> 00:58:52,720
amounts of it there isn't an there isn't

1373
00:58:57,030 --> 00:58:54,559
a known abiotic process that could

1374
00:58:58,309 --> 00:58:57,040
produce sort of that amount but don't

1375
00:58:59,990 --> 00:58:58,319
quote me on that

1376
00:59:02,549 --> 00:59:00,000
okay well

1377
00:59:04,789 --> 00:59:02,559
you know we're just speculating here one

1378
00:59:07,030 --> 00:59:04,799
non-expert to another

1379
00:59:08,870 --> 00:59:07,040
but uh that was that was somewhat my

1380
00:59:11,670 --> 00:59:08,880
memory as well that you could produce a

1381
00:59:14,309 --> 00:59:11,680
certain amount but the the depth of the

1382
00:59:17,349 --> 00:59:14,319
oxygen signature in the spectrum would

1383
00:59:19,910 --> 00:59:17,359
be uh an important factor in terms of

1384
00:59:22,309 --> 00:59:19,920
whether or not it could definitely be uh

1385
00:59:24,230 --> 00:59:22,319
could be abiotic or had to be uh due to

1386
00:59:25,829 --> 00:59:24,240
biology and there's the question of how

1387
00:59:27,750 --> 00:59:25,839
deep would it need to be to even see it

1388
00:59:30,230 --> 00:59:27,760

because remember you are looking at the

1389
00:59:31,670 --> 00:59:30,240
atmosphere of an exoplanet as it goes

1390
00:59:35,109 --> 00:59:31,680
into transit

1391
00:59:36,710 --> 00:59:35,119
yes yes i'm sorry my mind that's still

1392
00:59:38,789 --> 00:59:36,720
like every time i hear somebody talk

1393
00:59:40,309 --> 00:59:38,799
about it i just go like i know i

1394
00:59:42,150 --> 00:59:40,319
understand everything you're saying i

1395
00:59:45,589 --> 00:59:42,160
see your logical progression this feels

1396
00:59:50,950 --> 00:59:47,990
actually said exactly that black magic

1397
00:59:52,789 --> 00:59:50,960
so yeah it feels like and even for even

1398
00:59:56,309 --> 00:59:52,799
for us the non-experts who don't do

1399
00:59:59,190 --> 00:59:58,069
we've had someone on here explain it and

1400
01:00:00,470 --> 00:59:59,200
it's still

1401
01:00:01,910 --> 01:00:00,480
yeah

1402
01:00:03,589 --> 01:00:01,920
all right um

1403
01:00:06,069 --> 01:00:03,599
if the gas giant is anything like

1404
01:00:08,710 --> 01:00:06,079
jupiter with its uh with its massive

1405
01:00:11,190 --> 01:00:08,720
magnetic field wouldn't the radiation

1406
01:00:13,990 --> 01:00:11,200
belts be a negative factor in a viable

1407
01:00:15,750 --> 01:00:14,000
moon unless it itself had a massive

1408
01:00:20,950 --> 01:00:15,760
magnetic field

1409
01:00:23,510 --> 01:00:20,960
a very very that's a very um good

1410
01:00:26,230 --> 01:00:23,520
question jupiter's moons actually orbit

1411
01:00:27,589 --> 01:00:26,240
i believe inside of jupiter's magnet

1412
01:00:33,190 --> 01:00:27,599
magnetosphere

1413
01:00:36,789 --> 01:00:33,200

massive and i'm going to see

1414
01:00:38,789 --> 01:00:36,799
if i can pull find a diagram of it

1415
01:00:39,910 --> 01:00:38,799
because

1416
01:00:42,069 --> 01:00:39,920
um

1417
01:00:44,230 --> 01:00:42,079
my recollection from my graduals

1418
01:00:46,710 --> 01:00:44,240
graduate school days which was probably

1419
01:00:48,470 --> 01:00:46,720
about the time you were being born

1420
01:00:50,390 --> 01:00:48,480
yeah we're not discussing that and and

1421
01:00:53,030 --> 01:00:50,400
yet and yeah can we can we like we're

1422
01:00:54,829 --> 01:00:53,040
not discussing was that uh hubble you

1423
01:00:57,829 --> 01:00:54,839
weren't born when it launched

1424
01:00:59,670 --> 01:00:57,839
yeah the magnetic field of jupiter is

1425
01:01:01,990 --> 01:00:59,680
larger than the sun

1426
01:01:06,630 --> 01:01:02,000
yeah it's it's absolutely i'm seeing if

1427
01:01:11,109 --> 01:01:09,109
well because like google google knows

1428
01:01:12,789 --> 01:01:11,119
basically what generally speaking google

1429
01:01:14,390 --> 01:01:12,799
knows all or at least you can find

1430
01:01:15,750 --> 01:01:14,400
everything you need on google

1431
01:01:17,990 --> 01:01:15,760
um

1432
01:01:20,390 --> 01:01:18,000
i was at berkeley and imka depatter was

1433
01:01:22,630 --> 01:01:20,400
a jupiter expert there and she did a lot

1434
01:01:25,349 --> 01:01:22,640
of observations i remember it being

1435
01:01:26,789 --> 01:01:25,359
bigger than like however big you think

1436
01:01:28,300 --> 01:01:26,799
it is

1437
01:01:31,430 --> 01:01:28,310
it's bigger

1438
01:01:34,470 --> 01:01:31,440

[Laughter]

1439
01:01:36,950 --> 01:01:34,480
and it encapsulates

1440
01:01:39,829 --> 01:01:36,960
but the the question is is important

1441
01:01:40,950 --> 01:01:39,839
right i mean if you you've got the at

1442
01:01:42,549 --> 01:01:40,960
least in jupiter you've got the

1443
01:01:43,829 --> 01:01:42,559
kilometric radiation that's it's

1444
01:01:45,190 --> 01:01:43,839
bouncing up the

1445
01:01:46,789 --> 01:01:45,200
the charged particles that are bouncing

1446
01:01:49,910 --> 01:01:46,799
from the top to the bottom and top to

1447
01:01:51,750 --> 01:01:49,920
the bottom et cetera now if a planet is

1448
01:01:52,870 --> 01:01:51,760
flying through that and it doesn't have

1449
01:01:53,750 --> 01:01:52,880
its own

1450
01:01:56,230 --> 01:01:53,760
you know

1451
01:01:57,750 --> 01:01:56,240
magnetic field magnetic field to stop it

1452
01:01:59,349 --> 01:01:57,760
that that could that could have some

1453
01:02:00,789 --> 01:01:59,359
problems that could cause issues i i

1454
01:02:02,309 --> 01:02:00,799
think i mean that was part of the reason

1455
01:02:05,910 --> 01:02:02,319
why i made the assumption that that

1456
01:02:06,950 --> 01:02:05,920
yavin 4 is inside is a ganymede because

1457
01:02:08,950 --> 01:02:06,960
the assumption would be that it would

1458
01:02:11,029 --> 01:02:08,960
then be inside of the magnet meters here

1459
01:02:13,270 --> 01:02:11,039
of the planet now what this would do to

1460
01:02:15,589 --> 01:02:13,280
the electronic systems on the death star

1461
01:02:17,349 --> 01:02:15,599
is a completely other

1462
01:02:19,109 --> 01:02:17,359
question

1463
01:02:21,270 --> 01:02:19,119

you know we're assuming that maybe they

1464
01:02:22,150 --> 01:02:21,280
did really good shielding on it because

1465
01:02:24,950 --> 01:02:22,160
i mean

1466
01:02:28,230 --> 01:02:26,789
one good cosmic ray hit can take out a

1467
01:02:30,150 --> 01:02:28,240
death yeah yes

1468
01:02:32,390 --> 01:02:30,160
and we're also talking about the same

1469
01:02:35,190 --> 01:02:32,400
people who didn't put safety rails on

1470
01:02:37,750 --> 01:02:35,200
the giant chasms in the middle okay

1471
01:02:42,309 --> 01:02:40,069
ocean would have a field day we now know

1472
01:02:44,390 --> 01:02:42,319
why the thing blew up but that's not

1473
01:02:45,910 --> 01:02:44,400
that's neither here nor there but i mean

1474
01:02:48,309 --> 01:02:45,920
yeah i mean that's actually if you think

1475
01:02:50,710 --> 01:02:48,319
about the size of the magnetic field of

1476
01:02:52,069 --> 01:02:50,720
yavin prime it does actually the more

1477
01:02:54,150 --> 01:02:52,079
interesting question is actually why

1478
01:02:56,710 --> 01:02:54,160
didn't why did why was the death star

1479
01:02:59,270 --> 01:02:56,720
still functional

1480
01:03:05,109 --> 01:03:02,230
and much less able to condense a beam

1481
01:03:07,349 --> 01:03:05,119
and then send it out to destroy yeah

1482
01:03:12,069 --> 01:03:09,270
given how much for just just for the

1483
01:03:14,549 --> 01:03:12,079
record but nasa the space probe into

1484
01:03:16,789 --> 01:03:14,559
like juno this was a real issue it was

1485
01:03:18,390 --> 01:03:16,799
designed to survive the interaction with

1486
01:03:20,870 --> 01:03:18,400
the magnetic field and we had their

1487
01:03:23,190 --> 01:03:20,880
shielding on it that does this so

1488
01:03:25,029 --> 01:03:23,200

just i guess assume that the death star

1489
01:03:27,109 --> 01:03:25,039
has a lot of shielding

1490
01:03:29,190 --> 01:03:27,119
okay so but but

1491
01:03:30,309 --> 01:03:29,200
props to the the question the person

1492
01:03:31,670 --> 01:03:30,319
asking the question that you know

1493
01:03:33,829 --> 01:03:31,680
magnetic fields

1494
01:03:35,270 --> 01:03:33,839
uh you know in astronomy we say if we

1495
01:03:36,710 --> 01:03:35,280
can't explain it then we just invoke

1496
01:03:37,670 --> 01:03:36,720
magnetic fields right

1497
01:03:39,109 --> 01:03:37,680
um

1498
01:03:40,789 --> 01:03:39,119
here is one where we don't want to try

1499
01:03:42,829 --> 01:03:40,799
to invoke magnetic fields because they

1500
01:03:44,549 --> 01:03:42,839
would definitely confuse the system

1501
01:03:46,470 --> 01:03:44,559
yeah no

1502
01:03:48,150 --> 01:03:46,480
go ahead

1503
01:03:49,589 --> 01:03:48,160
no it's i was just gonna say that's also

1504
01:03:50,950 --> 01:03:49,599
the question you ask at the end of a

1505
01:03:53,190 --> 01:03:50,960
colloquium if you haven't been paying

1506
01:03:54,950 --> 01:03:53,200
attention yes what about the magnetic

1507
01:03:57,349 --> 01:03:54,960
fields

1508
01:03:58,870 --> 01:03:57,359
go ahead grant what's next um we had

1509
01:04:02,309 --> 01:03:58,880
someone in chat actually answer the

1510
01:04:04,630 --> 01:04:02,319
question uh 5.3 million kilometers 3.3

1511
01:04:06,470 --> 01:04:04,640
million miles wide on average the

1512
01:04:09,510 --> 01:04:06,480
magnetosphere

1513
01:04:12,870 --> 01:04:09,520

150 times wider than jupiter itself and

1514
01:04:14,470 --> 01:04:12,880
15 times wider than the sun

1515
01:04:15,750 --> 01:04:14,480
so i think it's safe to say that

1516
01:04:17,349 --> 01:04:15,760
ganymede

1517
01:04:18,870 --> 01:04:17,359
is

1518
01:04:22,549 --> 01:04:18,880
inside of that

1519
01:04:25,190 --> 01:04:22,559
yeah yeah the question is at what radius

1520
01:04:26,710 --> 01:04:25,200
uh would the you know the radiation

1521
01:04:27,990 --> 01:04:26,720
running up and down the magnetic fields

1522
01:04:29,430 --> 01:04:28,000
be important

1523
01:04:30,630 --> 01:04:29,440
you know because it's not going to be

1524
01:04:32,549 --> 01:04:30,640
all the way out and it's not going to be

1525
01:04:34,870 --> 01:04:32,559
all the way in so yeah there's going to

1526
01:04:36,950 --> 01:04:34,880
be some point where your

1527
01:04:38,630 --> 01:04:36,960
either the magnetic field itself is

1528
01:04:41,910 --> 01:04:38,640
causing more damage than the shield that

1529
01:04:43,750 --> 01:04:41,920
it's providing from from the solar wind

1530
01:04:46,069 --> 01:04:43,760
okay

1531
01:04:49,589 --> 01:04:46,079
all right so um

1532
01:04:54,390 --> 01:04:51,589
this is this is the you'll attitude the

1533
01:04:57,430 --> 01:04:54,400
next time you give this talk right

1534
01:04:59,349 --> 01:04:57,440
um speaking of atmospheres uh why does

1535
01:05:01,750 --> 01:04:59,359
venus have a thick atmosphere even when

1536
01:05:03,510 --> 01:05:01,760
it's so close to the sun why hasn't it

1537
01:05:04,789 --> 01:05:03,520
escaped into space like the mars

1538
01:05:09,670 --> 01:05:04,799

atmosphere

1539
01:05:11,349 --> 01:05:09,680
i knew somebody was going to ask me

1540
01:05:13,270 --> 01:05:11,359
about venus

1541
01:05:14,549 --> 01:05:13,280
well for one thing venus is about the

1542
01:05:16,069 --> 01:05:14,559
mass of the earth it's a little less

1543
01:05:18,230 --> 01:05:16,079
than the mass of the earth but it's

1544
01:05:19,910 --> 01:05:18,240
people call it earth's twin it's about

1545
01:05:23,589 --> 01:05:19,920
the mass of the earth mars is actually

1546
01:05:25,589 --> 01:05:23,599
significantly less massive than here

1547
01:05:27,029 --> 01:05:25,599
and the reason what lost mars at the

1548
01:05:29,829 --> 01:05:27,039
atmosphere is because it was less

1549
01:05:31,430 --> 01:05:29,839
massive it cooled and it lost its

1550
01:05:35,109 --> 01:05:31,440
magnetic field

1551
01:05:37,510 --> 01:05:35,119
the particles of the solar wind they hit

1552
01:05:39,910 --> 01:05:37,520
the atmosphere you begin to break apart

1553
01:05:41,990 --> 01:05:39,920
the molecules that are in the atmosphere

1554
01:05:44,069 --> 01:05:42,000
and once you once those molecules are

1555
01:05:45,589 --> 01:05:44,079
broken apart and they're lighter

1556
01:05:48,069 --> 01:05:45,599
they are moving faster and then they

1557
01:05:49,990 --> 01:05:48,079
escape and mars atmosphere effectively

1558
01:05:52,069 --> 01:05:50,000
evaporates so that's what happened to

1559
01:05:54,630 --> 01:05:52,079
mars

1560
01:05:57,510 --> 01:05:54,640
venus the atmosphere of venus is

1561
01:06:00,150 --> 01:05:57,520
actually made and frank you can help me

1562
01:06:03,430 --> 01:06:00,160
a bit on this it's sulfur

1563
01:06:06,710 --> 01:06:03,440

is it sulfur dioxide um

1564
01:06:09,510 --> 01:06:06,720
yeah it's very it's heavy carbon dioxide

1565
01:06:11,349 --> 01:06:09,520
i think it's carbon dioxide 90 something

1566
01:06:13,589 --> 01:06:11,359
percent carbon dioxide 90 something

1567
01:06:16,470 --> 01:06:13,599
percent carbon with sulfur so these are

1568
01:06:19,109 --> 01:06:16,480
not there's actually not a lot of water

1569
01:06:21,270 --> 01:06:19,119
interestingly in venus's atmosphere

1570
01:06:23,349 --> 01:06:21,280
it's all there is also no magnetic field

1571
01:06:25,270 --> 01:06:23,359
in venus because venus is orbiting so

1572
01:06:27,510 --> 01:06:25,280
slowly that it can't actually

1573
01:06:28,309 --> 01:06:27,520
maintain a magnetic field

1574
01:06:30,470 --> 01:06:28,319
so

1575
01:06:32,549 --> 01:06:30,480
basically you have these heavy heavy

1576
01:06:34,549 --> 01:06:32,559
particles in the atmosphere and the

1577
01:06:36,470 --> 01:06:34,559
heavier the particle is

1578
01:06:38,630 --> 01:06:36,480
the same amount of energy will cause

1579
01:06:40,390 --> 01:06:38,640
will mean that it moves slower so those

1580
01:06:43,349 --> 01:06:40,400
heavy molecules aren't going to be able

1581
01:06:44,829 --> 01:06:43,359
to go fast enough to actually sort of

1582
01:06:47,190 --> 01:06:44,839
evaporate

1583
01:06:49,670 --> 01:06:47,200
off whereas

1584
01:06:52,069 --> 01:06:49,680
hydrogen lighter things like hydrogen

1585
01:06:53,430 --> 01:06:52,079
are just going to go like see a later

1586
01:06:55,349 --> 01:06:53,440
and they're going to be they're going to

1587
01:06:57,029 --> 01:06:55,359
be gone if you're not being protected by

1588
01:06:59,430 --> 01:06:57,039

a magnetic field

1589
01:07:02,150 --> 01:06:59,440
so venus is actually dry

1590
01:07:04,069 --> 01:07:02,160
yeah the thing i remember about venus

1591
01:07:06,630 --> 01:07:04,079
is that it's got so much carbon dioxide

1592
01:07:09,109 --> 01:07:06,640
in its atmosphere but if you look at

1593
01:07:11,109 --> 01:07:09,119
like the limestone the calcium carbonate

1594
01:07:12,309 --> 01:07:11,119
at the bottom of our oceans

1595
01:07:14,390 --> 01:07:12,319
if you

1596
01:07:15,670 --> 01:07:14,400
heated up earth such that you got rid of

1597
01:07:18,230 --> 01:07:15,680
the oceans and all that calcium

1598
01:07:19,829 --> 01:07:18,240
carbonate turned into carbon dioxide

1599
01:07:22,549 --> 01:07:19,839
we'd have to use this thicker atmosphere

1600
01:07:25,270 --> 01:07:22,559
as venus yeah except we have a part we

1601
01:07:28,069 --> 01:07:25,280
have a we have a carbon cycle

1602
01:07:30,870 --> 01:07:28,079
yes yeah and we're a little further away

1603
01:07:32,789 --> 01:07:30,880
so we and we're further away so we're in

1604
01:07:34,950 --> 01:07:32,799
venus is like just inside the habitable

1605
01:07:36,789 --> 01:07:34,960
zone and we're st dead in the middle of

1606
01:07:38,150 --> 01:07:36,799
the habitable zone so we've got that

1607
01:07:41,270 --> 01:07:38,160
going for us

1608
01:07:42,630 --> 01:07:41,280
um we but but we also have a species

1609
01:07:44,870 --> 01:07:42,640
that is dumping carbon into the

1610
01:07:46,549 --> 01:07:44,880
atmosphere at an unprecedented rate and

1611
01:07:47,910 --> 01:07:46,559
that

1612
01:07:51,029 --> 01:07:47,920
you know

1613
01:07:53,109 --> 01:07:51,039

yeah wikipedia says it's 96.5

1614
01:07:55,349 --> 01:07:53,119
carbon dioxide carbon dioxide

1615
01:07:56,710 --> 01:07:55,359
yeah basically don't go to a vacation on

1616
01:07:59,349 --> 01:07:56,720
venus

1617
01:08:01,750 --> 01:07:59,359
it's not a good spot

1618
01:08:04,870 --> 01:08:01,760
short-lived vacation

1619
01:08:08,470 --> 01:08:06,710
how long did the soviet lander make it

1620
01:08:10,710 --> 01:08:08,480
was it like

1621
01:08:13,430 --> 01:08:10,720
venera probe you know landed got some

1622
01:08:15,190 --> 01:08:13,440
pictures and then it melted

1623
01:08:16,470 --> 01:08:15,200
the surface of venus is hot enough to

1624
01:08:19,030 --> 01:08:16,480
melt lead

1625
01:08:20,149 --> 01:08:19,040
there you go

1626
01:08:22,709 --> 01:08:20,159
that would do it

1627
01:08:24,229 --> 01:08:22,719
yeah um okay so wait a minute i'm going

1628
01:08:25,590 --> 01:08:24,239
to jump in here for a question here

1629
01:08:28,070 --> 01:08:25,600
because there was one thing that sort of

1630
01:08:31,590 --> 01:08:28,080
thing all right so you're talking about

1631
01:08:33,669 --> 01:08:31,600
yavin prime being the the gas giant

1632
01:08:35,110 --> 01:08:33,679
now this this i had to look up on

1633
01:08:36,870 --> 01:08:35,120
wikipedia

1634
01:08:39,510 --> 01:08:36,880
and yes it's a thing

1635
01:08:40,709 --> 01:08:39,520
um iv is the moon

1636
01:08:42,870 --> 01:08:40,719
yes yes

1637
01:08:45,189 --> 01:08:42,880
prime is the gas giant

1638
01:08:46,950 --> 01:08:45,199

okay so yavin prime is a gas giant

1639
01:08:48,390 --> 01:08:46,960
that's supposedly orbiting in the

1640
01:08:50,149 --> 01:08:48,400
habitable zones

1641
01:08:52,630 --> 01:08:50,159
yeah orbiting into the habitable zone of

1642
01:08:55,189 --> 01:08:52,640
probably a relatively sun-like star

1643
01:08:57,669 --> 01:08:55,199
relatively sunlight star okay so

1644
01:09:00,070 --> 01:08:57,679
do we have observations from kepler or

1645
01:09:02,309 --> 01:09:00,080
other places that give us

1646
01:09:04,829 --> 01:09:02,319
gas giants in a habitable zone around

1647
01:09:08,149 --> 01:09:04,839
such a star i mean

1648
01:09:09,749 --> 01:09:08,159
i have we actually seen something else i

1649
01:09:11,829 --> 01:09:09,759
remember you talked about the moons that

1650
01:09:13,910 --> 01:09:11,839
we've seen that we've got a hoth and

1651
01:09:15,110 --> 01:09:13,920
we've got a tatooine i think do we

1652
01:09:15,990 --> 01:09:15,120
actually have

1653
01:09:17,430 --> 01:09:16,000
a yacht

1654
01:09:20,709 --> 01:09:17,440
a yavin prime

1655
01:09:23,269 --> 01:09:20,719
um i remember there being a big deal and

1656
01:09:25,349 --> 01:09:23,279
this was when i was a wee little

1657
01:09:28,470 --> 01:09:25,359
right okay um

1658
01:09:30,789 --> 01:09:28,480
that there is a really big news article

1659
01:09:33,669 --> 01:09:30,799
virginis i think was the cis was the

1660
01:09:35,510 --> 01:09:33,679
constellation that they had found that

1661
01:09:37,110 --> 01:09:35,520
they had found a gas giant that was in

1662
01:09:39,269 --> 01:09:37,120
the habitable zone this is back when

1663
01:09:40,950 --> 01:09:39,279

they were just using the stellar the

1664
01:09:43,669 --> 01:09:40,960
doppler shifts so it was all massive

1665
01:09:45,510 --> 01:09:43,679
planets close in and so i remember i

1666
01:09:47,510 --> 01:09:45,520
think i had the clipping from the

1667
01:09:48,870 --> 01:09:47,520
washington post in an op taped in a

1668
01:09:50,229 --> 01:09:48,880
notebook

1669
01:09:52,870 --> 01:09:50,239
that it was this big deal that they

1670
01:09:54,709 --> 01:09:52,880
found a gas giant in the habitable zone

1671
01:09:56,390 --> 01:09:54,719
i don't want to say definitely yes but

1672
01:10:00,229 --> 01:09:56,400
it would shock me if somewhere in that

1673
01:10:03,750 --> 01:10:00,239
like 5 000 planets that we haven't found

1674
01:10:05,590 --> 01:10:03,760
a gas giant in the habitable zone the

1675
01:10:07,590 --> 01:10:05,600
other moment that all of sci-fi fans

1676
01:10:09,110 --> 01:10:07,600
went completely nuts for for planets is

1677
01:10:11,430 --> 01:10:09,120
when we found something around proxima

1678
01:10:13,350 --> 01:10:11,440
centauri because in about three

1679
01:10:16,550 --> 01:10:13,360
different sci-fi universes there's a

1680
01:10:19,830 --> 01:10:16,560
colony at proxima centauri so that

1681
01:10:21,510 --> 01:10:19,840
proceeded to have all of us go like

1682
01:10:24,310 --> 01:10:21,520
you know it's possible

1683
01:10:26,630 --> 01:10:24,320
it's possible oh my god

1684
01:10:28,149 --> 01:10:26,640
well i mean for me finding finding

1685
01:10:29,590 --> 01:10:28,159
something around proximal is like you

1686
01:10:32,470 --> 01:10:29,600
know all right there can be planets

1687
01:10:35,910 --> 01:10:32,480
around red dwarfs and red dwarfs are the

1688
01:10:37,590 --> 01:10:35,920

most numerous common stars out there

1689
01:10:39,350 --> 01:10:37,600
so if you don't have planets around

1690
01:10:41,030 --> 01:10:39,360
there you're you're lacking for planets

1691
01:10:44,790 --> 01:10:41,040
in the universe

1692
01:10:46,950 --> 01:10:44,800
yeah exactly for me the others

1693
01:10:49,750 --> 01:10:46,960
they found a planet around a star that

1694
01:10:51,830 --> 01:10:49,760
was in like an i think like a 10 billion

1695
01:10:53,590 --> 01:10:51,840
old year old cluster so like around a

1696
01:10:56,390 --> 01:10:53,600
really old star

1697
01:10:58,550 --> 01:10:56,400
and that resulted in extensive amounts

1698
01:11:00,709 --> 01:10:58,560
of um in case anyone noticed i'm a

1699
01:11:02,550 --> 01:11:00,719
complete sci-fi nerd it resulted in

1700
01:11:04,790 --> 01:11:02,560
extensive babylon five references that

1701
01:11:06,790 --> 01:11:04,800
we'd found zaha doom

1702
01:11:08,390 --> 01:11:06,800
um

1703
01:11:09,830 --> 01:11:08,400
so you know

1704
01:11:13,030 --> 01:11:09,840
for people that sort of really wonder

1705
01:11:15,110 --> 01:11:13,040
like it really is true that like sci-fi

1706
01:11:17,270 --> 01:11:15,120
we feed sci-fi you know so they're

1707
01:11:18,870 --> 01:11:17,280
pulling stuff you know the hubble images

1708
01:11:22,550 --> 01:11:18,880
have been used as backgrounds for how

1709
01:11:25,270 --> 01:11:22,560
many space shows over the last 30 years

1710
01:11:26,550 --> 01:11:25,280
yeah simultaneously it's actually poor

1711
01:11:28,550 --> 01:11:26,560
uh

1712
01:11:30,390 --> 01:11:28,560
poor advertising for the web space also

1713
01:11:32,630 --> 01:11:30,400

because you know star trek is always

1714
01:11:35,510 --> 01:11:32,640
using hubble images you know so in the

1715
01:11:36,790 --> 01:11:35,520
21st century webb doesn't get any again

1716
01:11:38,070 --> 01:11:36,800
any play doesn't it

1717
01:11:39,270 --> 01:11:38,080
yeah it doesn't

1718
01:11:41,830 --> 01:11:39,280
but the thing is like what you have to

1719
01:11:43,910 --> 01:11:41,840
realize is this is also we're also being

1720
01:11:46,630 --> 01:11:43,920
run by a bunch of nerds so we nicknamed

1721
01:11:48,950 --> 01:11:46,640
planets hoth in tatooine

1722
01:11:51,350 --> 01:11:48,960
because that shorthand for us

1723
01:11:53,030 --> 01:11:51,360
and i think somebody at some point i

1724
01:11:54,950 --> 01:11:53,040
don't think it was entirely a joke

1725
01:11:58,550 --> 01:11:54,960
suggested naming terrestrial planets in

1726
01:11:59,910 --> 01:11:58,560
the habitable zone m-class planets

1727
01:12:01,270 --> 01:11:59,920
like it's

1728
01:12:04,390 --> 01:12:01,280
we're nerds

1729
01:12:06,550 --> 01:12:04,400
but it also helps from a public a public

1730
01:12:07,590 --> 01:12:06,560
um facing perspective because it's

1731
01:12:09,750 --> 01:12:07,600
shorthand

1732
01:12:11,430 --> 01:12:09,760
yeah most a lot of people know if they

1733
01:12:13,030 --> 01:12:11,440
hear m-class planet they're at least

1734
01:12:15,270 --> 01:12:13,040
sort of aware of what that means and so

1735
01:12:17,110 --> 01:12:15,280
that's a nice shorthand for

1736
01:12:19,350 --> 01:12:17,120
how important a terrestrial planet in

1737
01:12:20,870 --> 01:12:19,360
the habitable zone of a star would be

1738
01:12:23,510 --> 01:12:20,880

okay

1739
01:12:26,229 --> 01:12:23,520
all right grant what else we got

1740
01:12:29,270 --> 01:12:26,239
uh i like this question but it is not

1741
01:12:30,950 --> 01:12:29,280
necessarily astronomy related um

1742
01:12:32,630 --> 01:12:30,960
why couldn't the discard death star just

1743
01:12:34,709 --> 01:12:32,640
shoot through the atmosphere of the gas

1744
01:12:36,630 --> 01:12:34,719
giant to hit the rebel base but then

1745
01:12:38,470 --> 01:12:36,640
that's talking about the power of the

1746
01:12:40,470 --> 01:12:38,480
death star and we're talking about the

1747
01:12:41,830 --> 01:12:40,480
power of the laser and the fact that

1748
01:12:44,709 --> 01:12:41,840
initially they were shooting through

1749
01:12:45,830 --> 01:12:44,719
more than just the atmosphere

1750
01:12:48,709 --> 01:12:45,840
he would have had to shoot through like

1751
01:12:49,910 --> 01:12:48,719
the whole planet and yeah that that

1752
01:12:51,669 --> 01:12:49,920
that's uh

1753
01:12:52,950 --> 01:12:51,679
that's all based on theoretical and this

1754
01:12:54,950 --> 01:12:52,960
is of course the story that you just

1755
01:12:56,870 --> 01:12:54,960
came up with yeah and this is also

1756
01:12:58,229 --> 01:12:56,880
assuming i mean if this is also assuming

1757
01:12:59,669 --> 01:12:58,239
that it didn't get fried when it went

1758
01:13:01,350 --> 01:12:59,679
through the magnetic field of yavin

1759
01:13:03,590 --> 01:13:01,360
prime so

1760
01:13:06,149 --> 01:13:03,600
true

1761
01:13:09,630 --> 01:13:06,159
um all right so uh

1762
01:13:12,229 --> 01:13:09,640
why haven't we been able to determine if

1763
01:13:15,510 --> 01:13:12,239

kepler-452-b has oxygen in its

1764
01:13:16,950 --> 01:13:15,520
atmosphere and if that's too specific

1765
01:13:19,350 --> 01:13:16,960
what kind of things do you need to go

1766
01:13:20,790 --> 01:13:19,360
through in order to determine something

1767
01:13:22,950 --> 01:13:20,800
like that having

1768
01:13:24,550 --> 01:13:22,960
it's not that strong of an absorption

1769
01:13:28,070 --> 01:13:24,560
line

1770
01:13:30,149 --> 01:13:28,080
so you need an incredibly

1771
01:13:32,070 --> 01:13:30,159
powerful you basically need a better

1772
01:13:34,950 --> 01:13:32,080
telescope

1773
01:13:37,510 --> 01:13:34,960
q jwst

1774
01:13:39,669 --> 01:13:37,520
you you you you you basically need you

1775
01:13:41,750 --> 01:13:39,679
need a better i mean i mean i it sounds

1776
01:13:43,189 --> 01:13:41,760
flippant but it's really not it's not a

1777
01:13:46,070 --> 01:13:43,199
strong line

1778
01:13:47,110 --> 01:13:46,080
it's not the strongest absorption line

1779
01:13:48,390 --> 01:13:47,120
that you're going to see in an

1780
01:13:49,830 --> 01:13:48,400
atmosphere

1781
01:13:51,830 --> 01:13:49,840
mia do you want to say something about

1782
01:13:52,870 --> 01:13:51,840
spectra and the resolution of spectra

1783
01:13:55,110 --> 01:13:52,880
and the different different

1784
01:13:57,270 --> 01:13:55,120
spectrographs and how that has evolved

1785
01:13:58,709 --> 01:13:57,280
over your ears okay so you've got two

1786
01:14:00,550 --> 01:13:58,719
problems that you're dealing with first

1787
01:14:02,790 --> 01:14:00,560
off is the amount of glass they're

1788
01:14:07,990 --> 01:14:02,800

literally the size of your primary

1789
01:14:10,470 --> 01:14:08,000
mirror jwst is 6.5 meters across

1790
01:14:12,470 --> 01:14:10,480
i think one of the hexagonal segments is

1791
01:14:14,070 --> 01:14:12,480
it's 18 hexagonal segments and one of

1792
01:14:16,790 --> 01:14:14,080
those segments at my right is about the

1793
01:14:18,070 --> 01:14:16,800
size of the kepler mirror

1794
01:14:20,229 --> 01:14:18,080
um

1795
01:14:21,830 --> 01:14:20,239
order of magnitude certainly one one of

1796
01:14:23,990 --> 01:14:21,840
them is certainly larger than the

1797
01:14:26,470 --> 01:14:24,000
spitzer mirror right then the spitzer so

1798
01:14:28,229 --> 01:14:26,480
these are these are you know these are

1799
01:14:30,709 --> 01:14:28,239
this is the biggest thing we've ever

1800
01:14:32,550 --> 01:14:30,719
pointed at exoplanet atmospheres like

1801
01:14:34,229 --> 01:14:32,560
ever so that's the first thing is that

1802
01:14:36,870 --> 01:14:34,239
the telescope can collect a lot more

1803
01:14:38,709 --> 01:14:36,880
light a lot faster

1804
01:14:40,870 --> 01:14:38,719
the second thing is that when we observe

1805
01:14:44,950 --> 01:14:40,880
with spectra the resolution of the

1806
01:14:46,950 --> 01:14:44,960
spectra is how finely in wavelength can

1807
01:14:48,630 --> 01:14:46,960
we determine a line

1808
01:14:51,189 --> 01:14:48,640
so that if you have a spectrograph

1809
01:14:53,510 --> 01:14:51,199
that's low resolution you might have a

1810
01:14:55,590 --> 01:14:53,520
line sitting here but if you have

1811
01:14:57,350 --> 01:14:55,600
another stronger line that's right here

1812
01:14:58,950 --> 01:14:57,360
they're going to get completely we call

1813
01:15:00,630 --> 01:14:58,960

it actually blended

1814
01:15:02,790 --> 01:15:00,640
together and you're just going to see

1815
01:15:06,229 --> 01:15:02,800
the one line that corresponds to the

1816
01:15:09,910 --> 01:15:07,270
so

1817
01:15:11,990 --> 01:15:09,920
oxygen 2 because it's a relatively weak

1818
01:15:13,590 --> 01:15:12,000
line you need both a lot of glass you

1819
01:15:15,350 --> 01:15:13,600
need a lot of light

1820
01:15:17,510 --> 01:15:15,360
hitting your mirror very quickly but you

1821
01:15:19,350 --> 01:15:17,520
also need high resolution spectra so

1822
01:15:20,550 --> 01:15:19,360
that you can differentiate okay here's

1823
01:15:22,470 --> 01:15:20,560
oxygen

1824
01:15:25,590 --> 01:15:22,480
right from all the other lines that are

1825
01:15:28,470 --> 01:15:25,600
right near it and that may be stronger

1826
01:15:30,950 --> 01:15:28,480
and so over time our spectra have become

1827
01:15:33,030 --> 01:15:30,960
higher and higher resolution so they've

1828
01:15:34,709 --> 01:15:33,040
been able to resolve the resolve

1829
01:15:37,030 --> 01:15:34,719
outlines that are very very close

1830
01:15:39,830 --> 01:15:37,040
together so what it looked like one line

1831
01:15:42,630 --> 01:15:39,840
we can now see it's actually two lines

1832
01:15:43,830 --> 01:15:42,640
and i don't know what i'm allowed to say

1833
01:15:46,149 --> 01:15:43,840
about

1834
01:15:47,990 --> 01:15:46,159
yeah that i'll wait for i don't want to

1835
01:15:50,790 --> 01:15:48,000
say something because i don't know like

1836
01:15:52,470 --> 01:15:50,800
what's public and what's not yeah so i

1837
01:15:53,669 --> 01:15:52,480
don't even know what

1838
01:15:55,030 --> 01:15:53,679

yes

1839
01:15:57,189 --> 01:15:55,040
but the other thing the other point is

1840
01:16:00,149 --> 01:15:57,199
that you know for our audience is that

1841
01:16:02,550 --> 01:16:00,159
um kepler was designed to just measure

1842
01:16:04,310 --> 01:16:02,560
light curves right and so kepler didn't

1843
01:16:07,030 --> 01:16:04,320
do any spectra it just measured light

1844
01:16:08,790 --> 01:16:07,040
curves you know the brightness of a

1845
01:16:10,470 --> 01:16:08,800
couple hundred thousand stars over and

1846
01:16:12,470 --> 01:16:10,480
over and over and over and over and over

1847
01:16:14,310 --> 01:16:12,480
and over again so it got the light

1848
01:16:16,470 --> 01:16:14,320
curves that went and found the dips and

1849
01:16:17,669 --> 01:16:16,480
everything in order to get the spectra

1850
01:16:20,709 --> 01:16:17,679
and look at the atmospheres you have to

1851
01:16:22,709 --> 01:16:20,719
do follow-up observations but most of

1852
01:16:24,390 --> 01:16:22,719
the kepler stars are too far away for

1853
01:16:26,149 --> 01:16:24,400
really good follow-up okay they're not

1854
01:16:27,910 --> 01:16:26,159
going to produce enough light you aren't

1855
01:16:29,350 --> 01:16:27,920
going to be able to to get enough

1856
01:16:32,310 --> 01:16:29,360
photons to be able to get a good

1857
01:16:34,390 --> 01:16:32,320
spectrum of it so the um the mission

1858
01:16:36,950 --> 01:16:34,400
that actually is gonna that's sampling

1859
01:16:38,870 --> 01:16:36,960
this the the exoplanets that we will be

1860
01:16:42,310 --> 01:16:38,880
able to do follow up with j with with

1861
01:16:45,590 --> 01:16:42,320
web uh is the test mission so um

1862
01:16:49,350 --> 01:16:45,600
unfortunately kepler 452b or whatever

1863
01:16:52,149 --> 01:16:49,360

462b i can't remember it's his number um

1864
01:16:53,830 --> 01:16:52,159
is is a great or understanding and we we

1865
01:16:55,750 --> 01:16:53,840
can figure out we can understand the

1866
01:16:57,350 --> 01:16:55,760
solar system but the follow-up

1867
01:16:59,030 --> 01:16:57,360
observations my understanding is it's

1868
01:17:00,550 --> 01:16:59,040
too far out there for us to get really

1869
01:17:02,390 --> 01:17:00,560
good follow-up observations and you

1870
01:17:04,229 --> 01:17:02,400
you've got this additional thing that

1871
01:17:06,149 --> 01:17:04,239
the o2 when i'm looking at sort of where

1872
01:17:08,550 --> 01:17:06,159
the o2 line is located it's located i

1873
01:17:10,310 --> 01:17:08,560
believe in the near infrared yeah

1874
01:17:11,830 --> 01:17:10,320
so and in the near infrared when we're

1875
01:17:13,189 --> 01:17:11,840
dealing with our atmosphere we actually

1876
01:17:14,550 --> 01:17:13,199
have sections of the atmosphere because

1877
01:17:16,950 --> 01:17:14,560
the water vapor in our atmosphere that

1878
01:17:20,229 --> 01:17:16,960
we can't see yeah

1879
01:17:22,070 --> 01:17:20,239
so we have to really do near-infrared

1880
01:17:23,669 --> 01:17:22,080
really really well we have to go to

1881
01:17:25,270 --> 01:17:23,679
space

1882
01:17:26,710 --> 01:17:25,280
which is also you know why we have a

1883
01:17:28,630 --> 01:17:26,720
brand new telescope too

1884
01:17:30,470 --> 01:17:28,640
[Laughter]

1885
01:17:32,390 --> 01:17:30,480
we'll talk about that next month yeah

1886
01:17:35,189 --> 01:17:32,400
that'll be that'll be when i was

1887
01:17:37,750 --> 01:17:35,199
deciding on topics it was this or

1888
01:17:39,750 --> 01:17:37,760

first light like

1889
01:17:41,669 --> 01:17:39,760
when we talk about first light with jwst

1890
01:17:43,510 --> 01:17:41,679
what do we mean and um

1891
01:17:44,950 --> 01:17:43,520
my former boss

1892
01:17:47,030 --> 01:17:44,960
when i was here said they're going to be

1893
01:17:49,669 --> 01:17:47,040
hearing so much about jwst for the next

1894
01:17:53,030 --> 01:17:49,679
year talk about star wars

1895
01:17:54,790 --> 01:17:53,040
yes i i i agree i thought that was a

1896
01:17:56,470 --> 01:17:54,800
fine thing you know

1897
01:17:57,350 --> 01:17:56,480
you can't be

1898
01:17:59,270 --> 01:17:57,360
yeah

1899
01:18:00,550 --> 01:17:59,280
you can't compete with the the real

1900
01:18:03,350 --> 01:18:00,560
thing

1901
01:18:05,510 --> 01:18:03,360
all right grant any more questions

1902
01:18:07,350 --> 01:18:05,520
yeah um okay

1903
01:18:08,709 --> 01:18:07,360
first off i want to head this off at the

1904
01:18:10,790 --> 01:18:08,719
past because it's going to get asked if

1905
01:18:12,870 --> 01:18:10,800
it hasn't already resolution is a term

1906
01:18:15,830 --> 01:18:12,880
that people hear a lot but it's usually

1907
01:18:18,550 --> 01:18:15,840
related to video outputs when you talk

1908
01:18:19,510 --> 01:18:18,560
about resolution in spectra what do you

1909
01:18:21,189 --> 01:18:19,520
mean

1910
01:18:23,270 --> 01:18:21,199
so when we talk about resolution with

1911
01:18:25,910 --> 01:18:23,280
spectra what we mean is how

1912
01:18:27,430 --> 01:18:25,920
how well we are able to differentiate

1913
01:18:31,270 --> 01:18:27,440

two spectral lines

1914
01:18:33,510 --> 01:18:31,280
close to each other you need very high

1915
01:18:34,950 --> 01:18:33,520
resolution to differentiate between them

1916
01:18:39,030 --> 01:18:34,960
so it's like can you differentiate

1917
01:18:42,390 --> 01:18:39,040
between two lines that are 10 nanometers

1918
01:18:43,990 --> 01:18:42,400
apart versus two nanometers so a higher

1919
01:18:45,590 --> 01:18:44,000
resolution spectra is going to be able

1920
01:18:48,310 --> 01:18:45,600
to differentiate between lines that are

1921
01:18:50,630 --> 01:18:48,320
two nanometers apart rather than you

1922
01:18:53,590 --> 01:18:50,640
know 10 nanometers and there's always a

1923
01:18:57,030 --> 01:18:53,600
trade-off between the resolution and

1924
01:18:59,510 --> 01:18:57,040
your uh wavelength coverage

1925
01:19:01,910 --> 01:18:59,520
so how much of the spectrum can you do

1926
01:19:03,910 --> 01:19:01,920
so oftentimes instruments will have one

1927
01:19:05,669 --> 01:19:03,920
sort of lower resolution spectrograph

1928
01:19:07,270 --> 01:19:05,679
that covers a wider wavelength range so

1929
01:19:08,790 --> 01:19:07,280
a wider range

1930
01:19:10,630 --> 01:19:08,800
that you can if you don't need that

1931
01:19:12,709 --> 01:19:10,640
really high resolution you can just use

1932
01:19:14,470 --> 01:19:12,719
that and then they'll have a really high

1933
01:19:16,550 --> 01:19:14,480
resolution spectrograph that has a

1934
01:19:18,310 --> 01:19:16,560
narrow wavelength range for when you

1935
01:19:20,149 --> 01:19:18,320
really really need that incredibly

1936
01:19:21,669 --> 01:19:20,159
incredibly sort of different you need

1937
01:19:23,350 --> 01:19:21,679
the differentiation between those really

1938
01:19:25,750 --> 01:19:23,360

really fine lines

1939
01:19:27,270 --> 01:19:25,760
and high resolution spectroscopy is is

1940
01:19:28,870 --> 01:19:27,280
it fair to say that that is one of the

1941
01:19:30,790 --> 01:19:28,880
hardest things as far as amount of

1942
01:19:33,270 --> 01:19:30,800
photons and

1943
01:19:35,110 --> 01:19:33,280
amount of light you have to bring in

1944
01:19:37,430 --> 01:19:35,120
it's it's one of the most difficult

1945
01:19:39,510 --> 01:19:37,440
things that is done in astronomy is high

1946
01:19:41,189 --> 01:19:39,520
resolution i mean imaging you're just

1947
01:19:42,550 --> 01:19:41,199
taking all the light and

1948
01:19:43,830 --> 01:19:42,560
and you're seeing the intensity of the

1949
01:19:46,070 --> 01:19:43,840
light

1950
01:19:47,430 --> 01:19:46,080
spectroscopy you're taking that that

1951
01:19:49,030 --> 01:19:47,440
intensity of light and then trying to

1952
01:19:51,270 --> 01:19:49,040
spread that out and trying to get the

1953
01:19:53,510 --> 01:19:51,280
intensity in there and the more finally

1954
01:19:56,229 --> 01:19:53,520
you spread that out the

1955
01:19:58,470 --> 01:19:56,239
the lower your intensity is and so

1956
01:20:00,070 --> 01:19:58,480
high resolution spectroscopy is often

1957
01:20:02,550 --> 01:20:00,080
really high-resolution spectroscopy has

1958
01:20:04,390 --> 01:20:02,560
to be done in very large telescopes um

1959
01:20:06,070 --> 01:20:04,400
with some of the most sophisticated

1960
01:20:08,870 --> 01:20:06,080
instruments that we have

1961
01:20:11,669 --> 01:20:08,880
you need lots of photons to do lots of

1962
01:20:15,669 --> 01:20:11,679
high-res spectrum

1963
01:20:17,830 --> 01:20:15,679

you need a very big photon bucket okay

1964
01:20:20,070 --> 01:20:17,840
all right um what sort of things do you

1965
01:20:23,430 --> 01:20:20,080
look at uh like what kind of spectral

1966
01:20:24,629 --> 01:20:23,440
lines would show or would you look for

1967
01:20:26,950 --> 01:20:24,639
for

1968
01:20:29,430 --> 01:20:26,960
a habitable planet or

1969
01:20:32,149 --> 01:20:29,440
existence of

1970
01:20:34,310 --> 01:20:32,159
like if you were looking for life or you

1971
01:20:36,390 --> 01:20:34,320
were looking for the right conditions to

1972
01:20:37,750 --> 01:20:36,400
show life what kind of spectra would you

1973
01:20:40,709 --> 01:20:37,760
look for

1974
01:20:42,950 --> 01:20:40,719
i would say water

1975
01:20:45,590 --> 01:20:42,960
actual water lines in the atmosphere

1976
01:20:46,550 --> 01:20:45,600
would be one for me

1977
01:20:49,030 --> 01:20:46,560
um

1978
01:20:51,110 --> 01:20:49,040
but again i'm not an expert in this you

1979
01:20:53,270 --> 01:20:51,120
know whatsoever i mean the first pass is

1980
01:20:55,430 --> 01:20:53,280
is it in the habitable zone

1981
01:20:57,030 --> 01:20:55,440
and is it a terrestrial planet because

1982
01:20:58,470 --> 01:20:57,040
we are not going to be able to figure

1983
01:21:00,550 --> 01:20:58,480
out what's going on on a moon around a

1984
01:21:02,310 --> 01:21:00,560
gas giant anytime soon

1985
01:21:05,030 --> 01:21:02,320
so it really needs to be a terrestrial

1986
01:21:06,629 --> 01:21:05,040
world so a world that is high density in

1987
01:21:08,470 --> 01:21:06,639
the habitable zone of a star that's like

1988
01:21:11,350 --> 01:21:08,480

cut one

1989
01:21:14,790 --> 01:21:11,360
and then you try to look for signatures

1990
01:21:17,030 --> 01:21:14,800
like oxygen's the big one o2

1991
01:21:19,430 --> 01:21:17,040
but you there's other signatures as well

1992
01:21:21,270 --> 01:21:19,440
i would if i saw water vapor in the

1993
01:21:23,590 --> 01:21:21,280
atmosphere like a lot of water vapor in

1994
01:21:25,910 --> 01:21:23,600
the atmosphere i would assume that you

1995
01:21:27,990 --> 01:21:25,920
maybe had a water cycle going on on that

1996
01:21:29,750 --> 01:21:28,000
planet that you had a magnetic field

1997
01:21:31,350 --> 01:21:29,760
that was protecting it

1998
01:21:33,030 --> 01:21:31,360
because if you don't have a magnetic

1999
01:21:35,590 --> 01:21:33,040
field that's protecting it the solar

2000
01:21:37,669 --> 01:21:35,600
wind can come in and sort of dissociate

2001
01:21:39,270 --> 01:21:37,679
break apart the water molecules and the

2002
01:21:40,870 --> 01:21:39,280
hydrogen is going to go see you later

2003
01:21:42,870 --> 01:21:40,880
off of the space

2004
01:21:43,910 --> 01:21:42,880
um

2005
01:21:47,910 --> 01:21:43,920
so

2006
01:21:49,189 --> 01:21:47,920
think of i don't know if um

2007
01:21:52,149 --> 01:21:49,199
you've got any

2008
01:21:53,750 --> 01:21:52,159
that um you know what i would start to

2009
01:21:56,709 --> 01:21:53,760
look for is i would look at the earth's

2010
01:21:57,990 --> 01:21:56,719
app what we do when we we discuss this

2011
01:21:59,590 --> 01:21:58,000
generally is we look at earth's

2012
01:22:02,149 --> 01:21:59,600
atmosphere what are the signatures that

2013
01:22:04,390 --> 01:22:02,159

we see in earth's atmosphere um

2014
01:22:05,590 --> 01:22:04,400
not all of those can be directly tied to

2015
01:22:06,390 --> 01:22:05,600
biology

2016
01:22:08,390 --> 01:22:06,400
but

2017
01:22:09,590 --> 01:22:08,400
similar like that i mean i think what's

2018
01:22:12,149 --> 01:22:09,600
going to happen which is going to be

2019
01:22:13,750 --> 01:22:12,159
fantastic over the next 30 50 years is

2020
01:22:16,149 --> 01:22:13,760
that we're going to suddenly develop

2021
01:22:18,070 --> 01:22:16,159
this family of as we've developed a

2022
01:22:20,229 --> 01:22:18,080
family of planets out there right and

2023
01:22:22,229 --> 01:22:20,239
they've exceeded our our our our

2024
01:22:25,830 --> 01:22:22,239
expectations right they blow our minds

2025
01:22:27,430 --> 01:22:25,840
on a month yeah we're going to develop a

2026
01:22:30,310 --> 01:22:27,440
family of

2027
01:22:33,110 --> 01:22:30,320
exoplanet atmosphere uh characteristics

2028
01:22:35,750 --> 01:22:33,120
that's going to challenge us to explain

2029
01:22:36,629 --> 01:22:35,760
well what the bloody blazes is going on

2030
01:22:39,030 --> 01:22:36,639
here

2031
01:22:41,270 --> 01:22:39,040
and honest and that is the ragged itch

2032
01:22:44,229 --> 01:22:41,280
exoplanet atmospheres i mean i when i

2033
01:22:46,790 --> 01:22:44,239
emailed ted to get the information for

2034
01:22:48,310 --> 01:22:46,800
the color of gavin prime i figured oh

2035
01:22:50,390 --> 01:22:48,320
there's got to be a paper out there

2036
01:22:52,390 --> 01:22:50,400
somebody has to have done it the answer

2037
01:22:53,510 --> 01:22:52,400
turned out to kind of be no

2038
01:22:55,270 --> 01:22:53,520

and he's like well this is what my

2039
01:22:56,950 --> 01:22:55,280
intuition is telling me but this isn't

2040
01:22:58,470 --> 01:22:56,960
really something that anybody's been

2041
01:22:59,350 --> 01:22:58,480
able to do

2042
01:23:01,030 --> 01:22:59,360
so

2043
01:23:02,709 --> 01:23:01,040
it's when we when we're talking about

2044
01:23:04,790 --> 01:23:02,719
these observations of exoplanet

2045
01:23:07,270 --> 01:23:04,800
atmospheres it isn't pi in the sky but

2046
01:23:11,110 --> 01:23:07,280
it is it is a longer term thing this is

2047
01:23:13,910 --> 01:23:11,120
this is 10 15 20 years look you know

2048
01:23:15,270 --> 01:23:13,920
we didn't have

2049
01:23:16,950 --> 01:23:15,280
other planets

2050
01:23:19,110 --> 01:23:16,960
30 years ago okay

2051
01:23:21,910 --> 01:23:19,120
30 years ago we did we didn't have other

2052
01:23:23,910 --> 01:23:21,920
planets 20 years ago

2053
01:23:26,709 --> 01:23:23,920
we were talking 30 years ago 1992 which

2054
01:23:29,030 --> 01:23:26,719
is 30 years ago oh god that was 30 years

2055
01:23:30,830 --> 01:23:29,040
it is 30 years okay

2056
01:23:33,189 --> 01:23:30,840
you can feel old too mia

2057
01:23:35,590 --> 01:23:33,199
[Laughter]

2058
01:23:37,030 --> 01:23:35,600
30 years ago we didn't know of any any

2059
01:23:38,310 --> 01:23:37,040
other planets now we have all these

2060
01:23:40,870 --> 01:23:38,320
other planets and we're starting to

2061
01:23:42,629 --> 01:23:40,880
understand atmospheres uh 30 years from

2062
01:23:45,110 --> 01:23:42,639
now which is one of the reasons i said

2063
01:23:46,709 --> 01:23:45,120

that was we'll have a whole a whole lot

2064
01:23:49,189 --> 01:23:46,719
of atmospheres and we'll still be

2065
01:23:50,390 --> 01:23:49,199
confused by it uh because you know

2066
01:23:52,950 --> 01:23:50,400
nature's

2067
01:23:54,790 --> 01:23:52,960
more inventive than uh than

2068
01:23:57,510 --> 01:23:54,800
our imaginations

2069
01:23:58,790 --> 01:23:57,520
yeah it's if um like if anybody if

2070
01:24:00,310 --> 01:23:58,800
anybody's ever played the video game

2071
01:24:02,790 --> 01:24:00,320
mass effect

2072
01:24:04,629 --> 01:24:02,800
um one of the professors at maryland

2073
01:24:08,870 --> 01:24:04,639
once commented that the exoplanets were

2074
01:24:12,470 --> 01:24:10,709
nature is always stranger than nature's

2075
01:24:13,830 --> 01:24:12,480
always stranger than fiction that's why

2076
01:24:15,350 --> 01:24:13,840
i love that when i was looking for a

2077
01:24:16,950 --> 01:24:15,360
quote to start up the discussion of the

2078
01:24:17,910 --> 01:24:16,960
planets i was just like oh this is

2079
01:24:19,910 --> 01:24:17,920
perfect

2080
01:24:21,270 --> 01:24:19,920
okay there are more things on heaven and

2081
01:24:22,870 --> 01:24:21,280
earth

2082
01:24:24,550 --> 01:24:22,880
all right so i think we're going to

2083
01:24:27,430 --> 01:24:24,560
leave it there because we're approaching

2084
01:24:30,149 --> 01:24:27,440
an hour and a half um and i will put it

2085
01:24:31,189 --> 01:24:30,159
into one final question for you mia

2086
01:24:33,590 --> 01:24:31,199
which is

2087
01:24:34,790 --> 01:24:33,600
not on this topic but is on next week's

2088
01:24:37,110 --> 01:24:34,800

topic

2089
01:24:39,590 --> 01:24:37,120
what is it that you are most excited

2090
01:24:41,270 --> 01:24:39,600
about or most anticipating with the web

2091
01:24:43,510 --> 01:24:41,280
space telescope

2092
01:24:48,310 --> 01:24:43,520
the thing we don't think

2093
01:24:52,310 --> 01:24:49,750
there are things that we're pretty sure

2094
01:24:54,950 --> 01:24:52,320
we're going to see every galaxy that

2095
01:24:56,629 --> 01:24:54,960
hubble has conceived january's taking a

2096
01:24:58,550 --> 01:24:56,639
spectrum

2097
01:25:00,390 --> 01:24:58,560
and so there are a lot of things that we

2098
01:25:02,070 --> 01:25:00,400
know that we're going to say that that

2099
01:25:04,229 --> 01:25:02,080
were that were that we're kind of

2100
01:25:06,310 --> 01:25:04,239
expecting right

2101
01:25:08,149 --> 01:25:06,320
we know when we look deep in an

2102
01:25:09,510 --> 01:25:08,159
extragalactic field that we're going to

2103
01:25:11,189 --> 01:25:09,520
see more galaxies that we're going to

2104
01:25:12,390 --> 01:25:11,199
see galaxies further back like we know

2105
01:25:14,870 --> 01:25:12,400
this right

2106
01:25:16,310 --> 01:25:14,880
but there's going to be something

2107
01:25:17,750 --> 01:25:16,320
and i think it's going to be in every

2108
01:25:19,110 --> 01:25:17,760
field it's going to be an exoplanets

2109
01:25:20,229 --> 01:25:19,120
it's going to be in stellar it's going

2110
01:25:23,270 --> 01:25:20,239
to be in

2111
01:25:24,709 --> 01:25:23,280
distant galaxies

2112
01:25:26,950 --> 01:25:24,719
there's going to be

2113
01:25:28,790 --> 01:25:26,960

something that just

2114
01:25:31,270 --> 01:25:28,800
changes the paradigm changes the

2115
01:25:33,590 --> 01:25:31,280
conversation that we absolutely didn't

2116
01:25:34,950 --> 01:25:33,600
expect and that's the thing i'm really

2117
01:25:36,149 --> 01:25:34,960
excited about now that doesn't mean i'm

2118
01:25:38,830 --> 01:25:36,159
not going to drool over the pretty

2119
01:25:43,189 --> 01:25:38,840
pictures that we're getting next week

2120
01:25:45,910 --> 01:25:43,199
but it's the thing that we didn't expect

2121
01:25:48,709 --> 01:25:45,920
it's that it's the unknown i mean it's

2122
01:25:50,790 --> 01:25:48,719
kind of like for hubble i we the image

2123
01:25:53,270 --> 01:25:50,800
you have behind you of these deep fields

2124
01:25:55,750 --> 01:25:53,280
of uh of galaxies right

2125
01:25:58,310 --> 01:25:55,760
we did not know we were gonna get that

2126
01:26:00,790 --> 01:25:58,320
with hubble right matter of fact um it

2127
01:26:03,110 --> 01:26:00,800
was quite a risk to put that much time

2128
01:26:05,669 --> 01:26:03,120
into doing a deep field and it was

2129
01:26:06,830 --> 01:26:05,679
director's discretionary correct

2130
01:26:09,750 --> 01:26:06,840
director's

2131
01:26:11,990 --> 01:26:09,760
discretionary this was bob this is bob

2132
01:26:13,830 --> 01:26:12,000
williams saying i'm going to throw 300

2133
01:26:16,790 --> 01:26:13,840
orbits at

2134
01:26:18,470 --> 01:26:16,800
one image and basically if

2135
01:26:20,870 --> 01:26:18,480
if it fails

2136
01:26:22,550 --> 01:26:20,880
yeah i'm fired

2137
01:26:24,149 --> 01:26:22,560
i'm going to go point the most powerful

2138
01:26:26,070 --> 01:26:24,159

telescope we have

2139
01:26:27,830 --> 01:26:26,080
for 300 orbits for those of you that are

2140
01:26:30,470 --> 01:26:27,840
listening that is an insane amount of

2141
01:26:32,870 --> 01:26:30,480
hubble time like crazy like ridiculous

2142
01:26:35,350 --> 01:26:32,880
and if anybody had proposed to go

2143
01:26:37,270 --> 01:26:35,360
through the allocation committee to

2144
01:26:38,709 --> 01:26:37,280
point hubble for 300 hours at nothing

2145
01:26:40,870 --> 01:26:38,719
for 300 orbits they would have been

2146
01:26:42,790 --> 01:26:40,880
laughed out of the room

2147
01:26:44,229 --> 01:26:42,800
and yet he said with his director's

2148
01:26:46,390 --> 01:26:44,239
discretionary which is time that the

2149
01:26:49,430 --> 01:26:46,400
director of space telescope could choose

2150
01:26:51,030 --> 01:26:49,440
to use as they see fit

2151
01:26:52,950 --> 01:26:51,040
he then said i'm going to point this at

2152
01:26:54,790 --> 01:26:52,960
nothing and i'm going to see what i see

2153
01:26:56,629 --> 01:26:54,800
now the one behind me is the ultra deep

2154
01:26:59,750 --> 01:26:56,639
field which was the second one that was

2155
01:27:01,030 --> 01:26:59,760
done but the original deep field

2156
01:27:05,830 --> 01:27:01,040
was a risk

2157
01:27:07,750 --> 01:27:05,840
it was an empty section of sky i think

2158
01:27:09,910 --> 01:27:07,760
it's what the size of a dime the eye and

2159
01:27:11,350 --> 01:27:09,920
a dime or something

2160
01:27:12,550 --> 01:27:11,360
at arm's length

2161
01:27:15,830 --> 01:27:12,560
and

2162
01:27:17,669 --> 01:27:15,840
there was they purposely picked

2163
01:27:18,870 --> 01:27:17,679

something but there was nothing there

2164
01:27:20,310 --> 01:27:18,880
and they could have gone out and they

2165
01:27:21,669 --> 01:27:20,320
could have seen nothing

2166
01:27:23,590 --> 01:27:21,679
and it could have been a complete dud

2167
01:27:25,990 --> 01:27:23,600
and instead

2168
01:27:27,669 --> 01:27:26,000
we got a field of not of stars but of

2169
01:27:29,510 --> 01:27:27,679
galaxies

2170
01:27:31,350 --> 01:27:29,520
where every single point of light behind

2171
01:27:34,310 --> 01:27:31,360
me is a galaxy

2172
01:27:37,430 --> 01:27:34,320
so i just used that as a as a

2173
01:27:39,430 --> 01:27:37,440
point for our audience that you know

2174
01:27:40,629 --> 01:27:39,440
we didn't expect that from hubble and

2175
01:27:42,149 --> 01:27:40,639
there will be things we don't expect

2176
01:27:43,990 --> 01:27:42,159
from web and

2177
01:27:45,510 --> 01:27:44,000
they're gonna make me a happy

2178
01:27:47,189 --> 01:27:45,520
they're gonna make honestly that's what

2179
01:27:48,550 --> 01:27:47,199
a lot of everyone happy that's i think

2180
01:27:49,510 --> 01:27:48,560
that's what we're all the most excited

2181
01:27:51,110 --> 01:27:49,520
about it's like the stuff we're

2182
01:27:52,870 --> 01:27:51,120
expecting we're like yeah that's great

2183
01:27:54,629 --> 01:27:52,880
it's gonna be nice science

2184
01:27:56,790 --> 01:27:54,639
it's the stuff that it's what's the

2185
01:27:58,709 --> 01:27:56,800
phrase of scientific discovery the the

2186
01:28:03,350 --> 01:27:58,719
most important moments in science are

2187
01:28:06,950 --> 01:28:05,030
you know i think that's a i think that's

2188
01:28:09,110 --> 01:28:06,960

a great way to end it okay

2189
01:28:10,790 --> 01:28:09,120
all right so uh

2190
01:28:13,510 --> 01:28:10,800
next month all right well first of all

2191
01:28:16,550 --> 01:28:13,520
next week july 12th

2192
01:28:18,550 --> 01:28:16,560
watch the nasa uh broadcast and see the

2193
01:28:21,510 --> 01:28:18,560
new images and spectra from the space

2194
01:28:24,870 --> 01:28:21,520
telescope uh the web space telescope and

2195
01:28:27,270 --> 01:28:24,880
then on august 2nd alex lockwood will

2196
01:28:28,470 --> 01:28:27,280
explain it all to you she'll have all

2197
01:28:29,910 --> 01:28:28,480
the answers

2198
01:28:31,430 --> 01:28:29,920
um and she

2199
01:28:34,629 --> 01:28:31,440
probably won't have that one thing we

2200
01:28:37,189 --> 01:28:34,639
don't expect yet but she will do a

2201
01:28:39,990 --> 01:28:37,199
fantastic job of explaining so thank you