1
00:00:16,810 --> 00:00:42,830
[Music]

2
00:00:42,840 --> 00:00:46,380
so

3
00:00:46,390 --> 00:01:10,830
[Music]

4
00:01:10,840 --> 00:01:14,340
so

5
00:02:34,830 --> 00:02:06,830
[Music]

6
00:02:34,840 --> 00:02:38,020
foreign

7
00:02:38,030 --> 00:02:49,589
[Music]

8
00:03:16,830 --> 00:02:49,920
foreign

9
00:03:55,930 --> 00:03:19,230
so

10
00:04:12,830 --> 00:03:58,830
[Music]

11
00:04:12,840 --> 00:04:18,280
man

12
00:04:40,830 --> 00:04:24,650
[Music]

13
00:04:53,990 --> 00:04:42,590

so

14
00:04:56,930 --> 00:04:54,000
[Music]

15
00:05:21,110 --> 00:04:56,940
tell me

16
00:05:24,629 --> 00:05:23,029
nasa's jet propulsion laboratory

17
00:05:27,270 --> 00:05:24,639
presents

18
00:05:29,350 --> 00:05:27,280
the von carmen lecture a series of talks

19
00:05:32,790 --> 00:05:29,360
by scigineers who are exploring

20
00:05:41,320 --> 00:05:32,800
our planet our solar system and all that

21
00:05:45,510 --> 00:05:42,950
[Music]

22
00:05:47,350 --> 00:05:45,520
hello everyone and a very chilling

23
00:05:48,870 --> 00:05:47,360
evening to you wherever you may be

24
00:05:50,950 --> 00:05:48,880
welcome to another remote edition of

25
00:05:51,990 --> 00:05:50,960
arvon carmen series i am brian white

26
00:05:55,110 --> 00:05:52,000
from jpl's office

27
00:05:57,830 --> 00:05:55,120
of communications and education this is

28
00:06:00,390 --> 00:05:57,840
galaxy of horrors tonight's talk will

29
00:06:02,550 --> 00:06:00,400
delve into the mysterious and terrifying

30
00:06:05,670 --> 00:06:02,560
phenomena throughout our universe

31
00:06:06,150 --> 00:06:05,680
reminding us how lucky we are to live on

32
00:06:08,469 --> 00:06:06,160
planet

33
00:06:10,150 --> 00:06:08,479
earth there are only a few things that

34
00:06:10,710 --> 00:06:10,160
keep us up at night these are only a few

35
00:06:12,469 --> 00:06:10,720
of them

36
00:06:13,990 --> 00:06:12,479
this is not everything but if you have

37
00:06:16,150 --> 00:06:14,000
questions on the mystifying and

38
00:06:18,469 --> 00:06:16,160

horrifying aspects of astrophysics

39
00:06:20,070 --> 00:06:18,479
and exoplanets we urge you to be

40
00:06:21,430 --> 00:06:20,080
involved in the conversation

41
00:06:23,110 --> 00:06:21,440
if you're watching on youtube or

42
00:06:24,870 --> 00:06:23,120
facebook live ask

43
00:06:26,790 --> 00:06:24,880
questions in the chat box and our

44
00:06:28,230 --> 00:06:26,800
diligent social media team

45
00:06:29,590 --> 00:06:28,240
will bring in as many as we can

46
00:06:30,870 --> 00:06:29,600
throughout the night now if you don't

47
00:06:32,710 --> 00:06:30,880
see the chat box

48
00:06:33,990 --> 00:06:32,720
go ahead and reload your page and it

49
00:06:36,390 --> 00:06:34,000
should be right there

50
00:06:38,629 --> 00:06:36,400
and on that note we ask if any technical

51
00:06:40,309 --> 00:06:38,639
issues do arise you just stick with us

52
00:06:42,469 --> 00:06:40,319
as we get them sorted out

53
00:06:44,230 --> 00:06:42,479
now at the end of our show tonight we're

54
00:06:44,950 --> 00:06:44,240
going to play our galaxy of horrors

55
00:06:47,110 --> 00:06:44,960
video

56
00:06:48,790 --> 00:06:47,120
made in the style of a classic monster

57
00:06:50,150 --> 00:06:48,800
movie trailer so make sure you stick

58
00:06:51,830 --> 00:06:50,160
around for that

59
00:06:53,430 --> 00:06:51,840
helping us with questions tonight will

60
00:06:58,390 --> 00:06:53,440
be public outreach specialist

61
00:07:00,469 --> 00:06:58,400
thalia rivera hi ethelia hi brian

62
00:07:01,830 --> 00:07:00,479
yo i understand the galaxy of horrors

63
00:07:04,550 --> 00:07:01,840

this whole series is something very

64
00:07:07,270 --> 00:07:04,560
close to your heart

65
00:07:09,589 --> 00:07:07,280
it is very close to my heart i actually

66
00:07:11,589 --> 00:07:09,599
produced this poster series last year

67
00:07:13,430 --> 00:07:11,599
with the help of some amazing artists

68
00:07:15,830 --> 00:07:13,440
and experts in the field

69
00:07:18,150 --> 00:07:15,840
and i was inspired by the by halloween

70
00:07:20,790 --> 00:07:18,160
to highlight the terrifying real worlds

71
00:07:22,629 --> 00:07:20,800
that exist that exist in our galaxy

72
00:07:24,469 --> 00:07:22,639
since the inception of the series we

73
00:07:26,469 --> 00:07:24,479
have begun to look at other mysterious

74
00:07:28,830 --> 00:07:26,479
entities in the universe though

75
00:07:29,990 --> 00:07:28,840
so be sure to check out our website

76
00:07:32,230 --> 00:07:30,000
exoplanets.nasa.gov

77
00:07:35,110 --> 00:07:32,240
later this month for a real treat and to

78
00:07:36,870 --> 00:07:35,120
learn more about our galaxy of horrors

79
00:07:38,790 --> 00:07:36,880
as a reminder we will be answering

80
00:07:40,550 --> 00:07:38,800
questions later on so please

81
00:07:42,550 --> 00:07:40,560
be sure to pop your questions into the

82
00:07:44,629 --> 00:07:42,560
chat on facebook and youtube and we will

83
00:07:46,309 --> 00:07:44,639
get to as many as possible

84
00:07:49,430 --> 00:07:46,319
now i think it's time we get this show

85
00:07:51,350 --> 00:07:49,440
started brian back to you

86
00:07:53,189 --> 00:07:51,360
i think it is we do have quite the panel

87
00:07:54,230 --> 00:07:53,199
of mad scientists with us tonight so

88
00:07:56,869 --> 00:07:54,240

first up

89
00:07:59,430 --> 00:07:56,879
an astrophysicist at jpl and the project

90
00:08:01,430 --> 00:07:59,440
scientist for nasa's new star satellite

91
00:08:03,510 --> 00:08:01,440
which observes x-ray emission from some

92
00:08:05,350 --> 00:08:03,520
of the most extreme

93
00:08:07,510 --> 00:08:05,360
energetic phenomena in the universe such

94
00:08:09,990 --> 00:08:07,520
as black holes neutron stars

95
00:08:11,589 --> 00:08:10,000
and supernova explosions he currently

96
00:08:13,270 --> 00:08:11,599
holds the record and i love this

97
00:08:14,629 --> 00:08:13,280
he holds the record for having

98
00:08:17,189 --> 00:08:14,639
discovered the most

99
00:08:19,270 --> 00:08:17,199
distant black hole known detected when

100
00:08:20,150 --> 00:08:19,280
the universe was less than 700 million

101
00:08:23,909 --> 00:08:20,160
years old

102
00:08:25,749 --> 00:08:23,919
or just five percent of its current age

103
00:08:27,189 --> 00:08:25,759
700 million years old just five percent

104
00:08:28,469 --> 00:08:27,199
of its current age here to talk about

105
00:08:31,510 --> 00:08:28,479
ghastly galaxies

106
00:08:35,589 --> 00:08:31,520
it's dr daniel stern hi daniel hey there

107
00:08:39,750 --> 00:08:38,550
oh i'm very happy what do you got for us

108
00:08:41,509 --> 00:08:39,760
tonight

109
00:08:43,829 --> 00:08:41,519
yeah hi i'm very happy to be here

110
00:08:45,430 --> 00:08:43,839
tonight i'm going to talk to you about

111
00:08:47,350 --> 00:08:45,440
us one of the things that keeps

112
00:08:48,630 --> 00:08:47,360
astronomers up at night on a little

113
00:08:51,350 --> 00:08:48,640

scary thing that's

114
00:08:53,110 --> 00:08:51,360
coming in our future um i'll have the

115
00:08:53,990 --> 00:08:53,120
little caveat that astronomers like

116
00:08:57,110 --> 00:08:54,000
staying up at night

117
00:08:58,550 --> 00:08:57,120
that's our usual job and uh this scary

118
00:09:00,230 --> 00:08:58,560
thing that's happening it's about four

119
00:09:01,910 --> 00:09:00,240
billion years from now so

120
00:09:03,990 --> 00:09:01,920
nothing to really really be worried

121
00:09:05,430 --> 00:09:04,000
about but um we are

122
00:09:07,190 --> 00:09:05,440
heading towards a collision with the

123
00:09:09,269 --> 00:09:07,200
nearest large galaxy to us

124
00:09:10,949 --> 00:09:09,279
the andromeda galaxy and here's a little

125
00:09:12,790 --> 00:09:10,959
graphic showing that

126
00:09:14,870 --> 00:09:12,800
um about a century ago using mount

127
00:09:17,110 --> 00:09:14,880
wilson observatory which is just above

128
00:09:19,990 --> 00:09:17,120
the hills of pasadena you can see that

129
00:09:21,829 --> 00:09:20,000
on clear days from down here

130
00:09:23,430 --> 00:09:21,839
so about 100 years ago and when hubble

131
00:09:25,509 --> 00:09:23,440
realized that

132
00:09:27,030 --> 00:09:25,519
galaxies are all moving away from us and

133
00:09:27,509 --> 00:09:27,040
the speed that they're moving away from

134
00:09:29,670 --> 00:09:27,519
us

135
00:09:30,790 --> 00:09:29,680
is proportional to how far away the

136
00:09:32,949 --> 00:09:30,800
galaxies

137
00:09:34,070 --> 00:09:32,959
are and that taught us the universe is

138
00:09:36,310 --> 00:09:34,080

expanding

139
00:09:37,910 --> 00:09:36,320
taught us about the big bang it taught

140
00:09:39,110 --> 00:09:37,920
us that there's these weird things in

141
00:09:40,949 --> 00:09:39,120
the universe like

142
00:09:42,630 --> 00:09:40,959
dark matter dark energy that

143
00:09:44,070 --> 00:09:42,640
jacqueline's going to teach us about in

144
00:09:46,949 --> 00:09:44,080
a little bit

145
00:09:49,190 --> 00:09:46,959
but um the one big exception to that all

146
00:09:51,590 --> 00:09:49,200
the galaxies are moving away from us

147
00:09:54,389 --> 00:09:51,600
is the nearest big galaxy to us

148
00:09:57,590 --> 00:09:54,399
andromeda is actually moving towards us

149
00:09:58,630 --> 00:09:57,600
it's coming at us about 70 miles per

150
00:10:01,750 --> 00:09:58,640
second

151
00:10:02,550 --> 00:10:01,760
so pretty fast um so kind of slow for an

152
00:10:04,550 --> 00:10:02,560
astronomer but

153
00:10:06,150 --> 00:10:04,560
anyhow it's moving towards us and uh

154
00:10:09,190 --> 00:10:06,160
this collision is going to happen about

155
00:10:11,829 --> 00:10:09,200
seven in about four billion years um so

156
00:10:14,310 --> 00:10:11,839
go to the next slide

157
00:10:15,910 --> 00:10:14,320
um so here is uh artists or partner

158
00:10:18,230 --> 00:10:15,920
computer simulation

159
00:10:19,509 --> 00:10:18,240
of what that collision might look like

160
00:10:22,150 --> 00:10:19,519
there's the milky way

161
00:10:23,430 --> 00:10:22,160
rotating around um zooming in we're

162
00:10:25,190 --> 00:10:23,440
going to fan out

163
00:10:27,350 --> 00:10:25,200

and you'll see that the milky way is a

164
00:10:29,269 --> 00:10:27,360
pretty flat galaxy

165
00:10:31,910 --> 00:10:29,279
andromeda that's coming in on the lower

166
00:10:32,389 --> 00:10:31,920
right right now is also a rather flat

167
00:10:34,949 --> 00:10:32,399
disc

168
00:10:36,949 --> 00:10:34,959
galaxy a little brighter in the center

169
00:10:39,269 --> 00:10:36,959
so these are two disc galaxies

170
00:10:41,030 --> 00:10:39,279
very similar um andromeda is a little

171
00:10:41,990 --> 00:10:41,040
bit bigger than the milky way we now

172
00:10:43,750 --> 00:10:42,000
think

173
00:10:46,710 --> 00:10:43,760
and um and they're coming towards each

174
00:10:47,350 --> 00:10:46,720
other and this is a slow-motion

175
00:10:48,710 --> 00:10:47,360
collision

176
00:10:50,389 --> 00:10:48,720
it's going to take a couple billion

177
00:10:53,030 --> 00:10:50,399
years but then we'll

178
00:10:55,030 --> 00:10:53,040
kind of slam through each other and

179
00:10:55,509 --> 00:10:55,040
galaxies are largely empty space you

180
00:10:57,750 --> 00:10:55,519
know there

181
00:11:00,550 --> 00:10:57,760
there's just even though there's 200

182
00:11:03,190 --> 00:11:00,560
billion stars or 300 billion stars

183
00:11:05,110 --> 00:11:03,200
in the milky way and a slightly bigger

184
00:11:06,150 --> 00:11:05,120
number in andromeda there's just so much

185
00:11:08,230 --> 00:11:06,160
empty space that the

186
00:11:10,389 --> 00:11:08,240
stars won't really collide so the two

187
00:11:12,310 --> 00:11:10,399
galaxies will pull through each other

188
00:11:14,550 --> 00:11:12,320

the gravity will pull them towards each

189
00:11:16,790 --> 00:11:14,560
other and we'll end up in about seven

190
00:11:20,310 --> 00:11:16,800
billion years as a sort of merged

191
00:11:23,750 --> 00:11:20,320
single galaxy um more disk more

192
00:11:26,710 --> 00:11:23,760
elliptical shape than disky or flat

193
00:11:27,590 --> 00:11:26,720
um and so the uh this is from a press

194
00:11:29,910 --> 00:11:27,600
release out of

195
00:11:31,269 --> 00:11:29,920
the space telescope science institute a

196
00:11:34,870 --> 00:11:31,279
couple years ago

197
00:11:37,750 --> 00:11:34,880
um we go to the next slide and um

198
00:11:39,350 --> 00:11:37,760
the big result what from their work that

199
00:11:39,750 --> 00:11:39,360
this press release was reporting on is

200
00:11:42,870 --> 00:11:39,760
that

201
00:11:45,910 --> 00:11:42,880
we knew from hubble's day a century ago

202
00:11:47,430 --> 00:11:45,920
that andromeda was moving towards us but

203
00:11:49,190 --> 00:11:47,440
using hubble they were able to see the

204
00:11:52,389 --> 00:11:49,200
transverse motion to see whether

205
00:11:54,550 --> 00:11:52,399
it was going to go by us or slam into us

206
00:11:55,910 --> 00:11:54,560
and using hubble and careful

207
00:11:57,030 --> 00:11:55,920
measurements over a decade they were

208
00:11:57,990 --> 00:11:57,040
able to see that were pretty much on a

209
00:12:00,389 --> 00:11:58,000
head-on

210
00:12:02,069 --> 00:12:00,399
collision and so what i love about this

211
00:12:04,389 --> 00:12:02,079
press release is they showed uh

212
00:12:06,310 --> 00:12:04,399
some images of the night sky over the

213
00:12:07,990 --> 00:12:06,320

next several billion years

214
00:12:10,389 --> 00:12:08,000
and so this is a current day version you

215
00:12:12,230 --> 00:12:10,399
see the milky way um

216
00:12:13,750 --> 00:12:12,240
has that big swath that you can see in a

217
00:12:16,949 --> 00:12:13,760
dark night sky

218
00:12:17,910 --> 00:12:16,959
um across the world and then um at sort

219
00:12:19,910 --> 00:12:17,920
of 11 o'clock

220
00:12:21,590 --> 00:12:19,920
you see a little thing that's andromeda

221
00:12:22,870 --> 00:12:21,600
which you can see with your naked eye on

222
00:12:26,069 --> 00:12:22,880
a dark side

223
00:12:27,590 --> 00:12:26,079
let's go to the next slide about 2

224
00:12:29,430 --> 00:12:27,600
billion years from now

225
00:12:31,269 --> 00:12:29,440
andromeda will be much bigger on the sky

226
00:12:32,790 --> 00:12:31,279
as it comes towards us and it will start

227
00:12:36,310 --> 00:12:32,800
looking more impressive

228
00:12:36,629 --> 00:12:36,320
on next one about 3.8 billion years from

229
00:12:38,470 --> 00:12:36,639
now

230
00:12:40,230 --> 00:12:38,480
the andromeda will be getting quite

231
00:12:42,069 --> 00:12:40,240
close to us and will look really

232
00:12:44,710 --> 00:12:42,079
beautiful in the night sky

233
00:12:46,069 --> 00:12:44,720
um but then the collision happens and

234
00:12:49,190 --> 00:12:46,079
this is sort of like the car

235
00:12:50,710 --> 00:12:49,200
rolling over and we're on earth in the

236
00:12:53,750 --> 00:12:50,720
midst of this collision

237
00:12:54,470 --> 00:12:53,760
next slide um about 100 million years

238
00:12:56,949 --> 00:12:54,480

later

239
00:12:58,710 --> 00:12:56,959
we're just like gas hits each other

240
00:13:00,389 --> 00:12:58,720
stars start forming

241
00:13:01,829 --> 00:13:00,399
um and we're rotating around in these

242
00:13:05,030 --> 00:13:01,839
colliding galaxy and

243
00:13:05,990 --> 00:13:05,040
some math next slide another 100 million

244
00:13:09,190 --> 00:13:06,000
years later at

245
00:13:11,430 --> 00:13:09,200
3.9 billion years um the whole sky we're

246
00:13:14,150 --> 00:13:11,440
in the middle of this big collision

247
00:13:14,629 --> 00:13:14,160
on next slide four billion years from

248
00:13:16,710 --> 00:13:14,639
now

249
00:13:17,670 --> 00:13:16,720
where andromeda has kind of moved away

250
00:13:20,150 --> 00:13:17,680
from us

251
00:13:21,910 --> 00:13:20,160
and then it's going to pull back in next

252
00:13:23,750 --> 00:13:21,920
slide

253
00:13:25,509 --> 00:13:23,760
um five billion years from now and you

254
00:13:26,150 --> 00:13:25,519
can still kind of separate out the milky

255
00:13:29,269 --> 00:13:26,160
way

256
00:13:31,590 --> 00:13:29,279
and andromeda as we crash in together

257
00:13:33,190 --> 00:13:31,600
and then the final slide um seven

258
00:13:37,269 --> 00:13:33,200
billion years from now

259
00:13:40,150 --> 00:13:37,279
and we're just in one merged galaxy um

260
00:13:40,790 --> 00:13:40,160
so kind of a big cosmic fireworks from

261
00:13:43,990 --> 00:13:40,800
this

262
00:13:46,550 --> 00:13:44,000
galaxy collision um

263
00:13:48,310 --> 00:13:46,560

one of the the two things that um even

264
00:13:50,230 --> 00:13:48,320
though stars are unlikely to

265
00:13:51,430 --> 00:13:50,240
hit each other during this collision the

266
00:13:53,350 --> 00:13:51,440
two things that are going to happen

267
00:13:55,590 --> 00:13:53,360
their stars will form

268
00:13:57,110 --> 00:13:55,600
and that can create a lot of energy and

269
00:13:58,550 --> 00:13:57,120
supernova going off

270
00:14:00,310 --> 00:13:58,560
and then the black holes in the center

271
00:14:02,230 --> 00:14:00,320
of the galaxies are likely to start

272
00:14:03,430 --> 00:14:02,240
feeding more and we might turn into a

273
00:14:06,949 --> 00:14:03,440
quasar which

274
00:14:10,069 --> 00:14:06,959
can put out a lot of gamma rays but uh

275
00:14:10,710 --> 00:14:10,079
that's that's the ghastly galaxy

276
00:14:13,750 --> 00:14:10,720
collision

277
00:14:15,430 --> 00:14:13,760
that's on our in our future well that's

278
00:14:17,110 --> 00:14:15,440
going to keep me up at night as you just

279
00:14:18,550 --> 00:14:17,120
said but not in the fun i'm gonna look

280
00:14:18,949 --> 00:14:18,560
up at stars that's something that i'm

281
00:14:20,629 --> 00:14:18,959
gonna

282
00:14:22,629 --> 00:14:20,639
think about turning into galaxy soup

283
00:14:23,829 --> 00:14:22,639
there um

284
00:14:25,750 --> 00:14:23,839
looks like there's a lot of questions

285
00:14:29,030 --> 00:14:25,760
coming in so what's on our audience's

286
00:14:34,310 --> 00:14:32,150
yeah so our audience would like to know

287
00:14:35,430 --> 00:14:34,320
uh a lot of things about what you just

288
00:14:38,470 --> 00:14:35,440

talked about daniel

289
00:14:40,150 --> 00:14:38,480
um but dwayne on facebook is asking

290
00:14:42,150 --> 00:14:40,160
which will happen first

291
00:14:43,670 --> 00:14:42,160
the collision of the andrum with the

292
00:14:45,910 --> 00:14:43,680
andromeda galaxy in

293
00:14:48,710 --> 00:14:45,920
our galaxy or the sun running out of

294
00:14:50,870 --> 00:14:48,720
fuel and consuming the earth

295
00:14:52,470 --> 00:14:50,880
great question dwayne and they both

296
00:14:55,030 --> 00:14:52,480
happen on pretty similar

297
00:14:56,870 --> 00:14:55,040
time scales just shy of four four

298
00:14:59,430 --> 00:14:56,880
billion years from now

299
00:15:00,310 --> 00:14:59,440
so um it's going to be a kind of nasty

300
00:15:03,590 --> 00:15:00,320
time to be

301
00:15:04,870 --> 00:15:03,600
on earth at that time as the sun runs

302
00:15:09,910 --> 00:15:04,880
out of fuel and

303
00:15:14,389 --> 00:15:12,790
next question great yeah we got a chance

304
00:15:16,870 --> 00:15:14,399
for daniel and we'll move on

305
00:15:18,949 --> 00:15:16,880
yes all right well so we know that the

306
00:15:21,470 --> 00:15:18,959
universe is a really really big place

307
00:15:23,990 --> 00:15:21,480
um and folks want to know uh

308
00:15:27,189 --> 00:15:24,000
specifically bingo on youtube

309
00:15:27,990 --> 00:15:27,199
is asking how close to the center of the

310
00:15:31,749 --> 00:15:28,000
universe

311
00:15:39,030 --> 00:15:35,990
um interesting question bingo we

312
00:15:40,710 --> 00:15:39,040
it's sort of anti-intuitive and probably

313
00:15:42,710 --> 00:15:40,720

i would be challenged to answering this

314
00:15:43,829 --> 00:15:42,720
right now maybe jacqueline wants to take

315
00:15:46,310 --> 00:15:43,839
a shot at it

316
00:15:48,870 --> 00:15:46,320
but um there is no center to the

317
00:15:51,269 --> 00:15:48,880
universe it's all just expanding

318
00:15:53,110 --> 00:15:51,279
but we actually think right now that

319
00:15:55,590 --> 00:15:53,120
it's infinitely big and it's just

320
00:15:58,790 --> 00:15:55,600
getting bigger so there is no center

321
00:16:00,310 --> 00:15:58,800
um andromeda if you're on andromeda it

322
00:16:02,150 --> 00:16:00,320
also looks like every galaxy is

323
00:16:05,269 --> 00:16:02,160
moving away from you except for the

324
00:16:07,269 --> 00:16:05,279
milky way if you're on another galaxy

325
00:16:08,389 --> 00:16:07,279
um again everything looks like it's

326
00:16:11,269 --> 00:16:08,399
moving away from you

327
00:16:12,870 --> 00:16:11,279
and you would also measure a hub on a

328
00:16:13,670 --> 00:16:12,880
planet orbiting a star in any of those

329
00:16:15,749 --> 00:16:13,680
galaxies

330
00:16:18,230 --> 00:16:15,759
sees that same thing no one's in the

331
00:16:22,069 --> 00:16:19,990
very cool now we'll be hearing more from

332
00:16:23,590 --> 00:16:22,079
dr stern near the end of the show but

333
00:16:25,430 --> 00:16:23,600
our next speaker is also an

334
00:16:28,310 --> 00:16:25,440
astrophysicist here at jpl

335
00:16:30,150 --> 00:16:28,320
her research tests the cdm paradigm by

336
00:16:32,710 --> 00:16:30,160
connecting galaxy clusters

337
00:16:35,350 --> 00:16:32,720
to cosmological parameter tensions and

338
00:16:37,350 --> 00:16:35,360

alternative models of dark matter

339
00:16:39,189 --> 00:16:37,360
dr mccleary is an active collaborator

340
00:16:42,790 --> 00:16:39,199
with the super pressure balloon born

341
00:16:44,470 --> 00:16:42,800
imaging telescope super bit

342
00:16:45,990 --> 00:16:44,480
project which will deliver space like

343
00:16:46,949 --> 00:16:46,000
imaging at a fraction of the cost

344
00:16:49,110 --> 00:16:46,959
tonight

345
00:16:50,550 --> 00:16:49,120
delving deeper into the mysteries of

346
00:16:54,230 --> 00:16:50,560
dark matter is dr

347
00:16:57,829 --> 00:16:54,240
jacqueline mccleary hey jacqueline

348
00:16:59,670 --> 00:16:57,839
hello uh i'm jacqueline and tonight

349
00:17:02,150 --> 00:16:59,680
we are going to delve into one of the

350
00:17:03,910 --> 00:17:02,160
deepest darkest mysteries there is

351
00:17:05,990 --> 00:17:03,920
but don't worry this cosmic mystery is

352
00:17:07,189 --> 00:17:06,000
only mildly horrifying

353
00:17:09,870 --> 00:17:07,199
if there's one thing you should take

354
00:17:13,029 --> 00:17:09,880
away from tonight it's this

355
00:17:13,750 --> 00:17:13,039
81.5 percent about four-fifths of all

356
00:17:16,150 --> 00:17:13,760
matter is

357
00:17:17,590 --> 00:17:16,160
dark by matter i mean anything that

358
00:17:18,390 --> 00:17:17,600
seems to interact through the force of

359
00:17:20,949 --> 00:17:18,400
gravity

360
00:17:23,110 --> 00:17:20,959
and by dark i mean it doesn't appear to

361
00:17:24,630 --> 00:17:23,120
emit or absorb any light

362
00:17:26,949 --> 00:17:24,640
this is where dark matter gets its

363
00:17:29,110 --> 00:17:26,959

rather eerie nickname

364
00:17:30,470 --> 00:17:29,120
we know that dark matter has to be there

365
00:17:32,390 --> 00:17:30,480
because of the way it pulls on the

366
00:17:35,110 --> 00:17:32,400
matter that we can see

367
00:17:35,750 --> 00:17:35,120
stars and gas and galaxies let's look at

368
00:17:39,669 --> 00:17:35,760
an example

369
00:17:43,750 --> 00:17:42,470
one of the most important clues to the

370
00:17:45,909 --> 00:17:43,760
existence of dark matter

371
00:17:46,950 --> 00:17:45,919
comes from how galaxies rotate how they

372
00:17:48,470 --> 00:17:46,960
spin

373
00:17:51,029 --> 00:17:48,480
what you would expect from normal

374
00:17:53,110 --> 00:17:51,039
physics is the scenario on the left

375
00:17:54,070 --> 00:17:53,120
as you move further out from the center

376
00:17:56,470 --> 00:17:54,080
of a galaxy

377
00:17:57,510 --> 00:17:56,480
the stars and gas move more slowly in

378
00:17:59,510 --> 00:17:57,520
the same way that

379
00:18:02,310 --> 00:17:59,520
orbits the sun more slowly than the

380
00:18:05,190 --> 00:18:02,320
earth but mercury orbits faster

381
00:18:07,990 --> 00:18:05,200
however in the 1970s astronomer vera

382
00:18:10,070 --> 00:18:08,000
rubin found something very surprising

383
00:18:11,029 --> 00:18:10,080
galaxies rotate like the one on the

384
00:18:12,630 --> 00:18:11,039
right

385
00:18:14,549 --> 00:18:12,640
it doesn't matter how far out you go

386
00:18:17,430 --> 00:18:14,559
from the center the stars and gas

387
00:18:18,070 --> 00:18:17,440
move at the same velocity so rather than

388
00:18:19,830 --> 00:18:18,080

orbiting

389
00:18:22,150 --> 00:18:19,840
rather than spinning like the solar

390
00:18:24,230 --> 00:18:22,160
system galaxies rotate more like a

391
00:18:27,510 --> 00:18:24,240
frisbee or a record

392
00:18:29,669 --> 00:18:27,520
this was a huge surprise

393
00:18:32,310 --> 00:18:29,679
this type of rotation is only possible

394
00:18:34,070 --> 00:18:32,320
if galaxies are embedded in a vast cloud

395
00:18:36,870 --> 00:18:34,080
containing much more matter

396
00:18:40,150 --> 00:18:36,880
than just visible stars and gas about

397
00:18:42,310 --> 00:18:40,160
five to ten times more matter

398
00:18:43,270 --> 00:18:42,320
so this was a huge surprise when it was

399
00:18:45,110 --> 00:18:43,280
first discovered

400
00:18:47,190 --> 00:18:45,120
and it's not the only line of evidence

401
00:18:50,710 --> 00:18:47,200
we have uh let's look at another way

402
00:18:54,830 --> 00:18:50,720
next slide this is an

403
00:18:56,470 --> 00:18:54,840
image of an object designated max

404
00:18:59,830 --> 00:18:56,480
j1206.2-084

405
00:19:02,230 --> 00:18:59,840
which we will call max g1206 for short

406
00:19:04,310 --> 00:19:02,240
this is a galaxy cluster a structure

407
00:19:06,630 --> 00:19:04,320
that consists of hundreds of galaxies

408
00:19:08,710 --> 00:19:06,640
all located in the same place

409
00:19:10,230 --> 00:19:08,720
most of the galaxies that you can see in

410
00:19:10,789 --> 00:19:10,240
this image aren't actually part of the

411
00:19:12,789 --> 00:19:10,799
cluster

412
00:19:15,110 --> 00:19:12,799
they're behind it and if you look

413
00:19:17,430 --> 00:19:15,120

closely you can see all sorts of weird

414
00:19:19,430 --> 00:19:17,440
stretching and curving of those galaxies

415
00:19:20,470 --> 00:19:19,440
and specifically around the center of

416
00:19:22,710 --> 00:19:20,480
the image

417
00:19:25,430 --> 00:19:22,720
this isn't an accident this is happening

418
00:19:27,190 --> 00:19:25,440
because max j-1206 is so heavy

419
00:19:28,470 --> 00:19:27,200
it's actually warping the fabric of

420
00:19:29,909 --> 00:19:28,480
space-time

421
00:19:32,630 --> 00:19:29,919
bending the light from the galaxy

422
00:19:33,430 --> 00:19:32,640
sitting behind it astrophysicists like

423
00:19:35,750 --> 00:19:33,440
me

424
00:19:37,830 --> 00:19:35,760
weigh galaxy clusters by carefully

425
00:19:39,510 --> 00:19:37,840
measuring the shapes and positions of

426
00:19:42,230 --> 00:19:39,520
these warped galaxies

427
00:19:44,150 --> 00:19:42,240
every time we look we find a mass far

428
00:19:46,710 --> 00:19:44,160
larger than what you'd get if you just

429
00:19:48,630 --> 00:19:46,720
tallied up the clusters stars and gas

430
00:19:50,549 --> 00:19:48,640
about five times more

431
00:19:52,310 --> 00:19:50,559
there's literally more to galaxy

432
00:19:55,029 --> 00:19:52,320
clusters than meets the eye

433
00:19:56,950 --> 00:19:55,039
they're mostly made of dark matter the

434
00:19:59,190 --> 00:19:56,960
blue glow on the right side of the image

435
00:20:00,390 --> 00:19:59,200
is a visual representation of this halo

436
00:20:03,430 --> 00:20:00,400
of dark matter

437
00:20:06,230 --> 00:20:03,440
for cluster max j1206

438
00:20:07,909 --> 00:20:06,240

all galaxy clusters have halos of dark

439
00:20:09,590 --> 00:20:07,919
matter like this

440
00:20:11,350 --> 00:20:09,600
but it's not just in galaxies and

441
00:20:13,430 --> 00:20:11,360
clusters dark matter

442
00:20:15,240 --> 00:20:13,440
even affects how galaxies are arranged

443
00:20:16,470 --> 00:20:15,250
in the entire universe

444
00:20:20,230 --> 00:20:16,480
[Music]

445
00:20:21,990 --> 00:20:20,240
let's take a look at the next slide

446
00:20:24,230 --> 00:20:22,000
so this is one of my favorite pictures

447
00:20:26,470 --> 00:20:24,240
in astronomy it comes from the two

448
00:20:28,390 --> 00:20:26,480
degree field galaxy redshift survey

449
00:20:30,710 --> 00:20:28,400
an incredible scientific effort that

450
00:20:33,590 --> 00:20:30,720
pinpointed the 3d location

451
00:20:34,070 --> 00:20:33,600
of almost 250 000 galaxies their

452
00:20:36,070 --> 00:20:34,080
position

453
00:20:37,669 --> 00:20:36,080
on the sky and their distance away from

454
00:20:39,669 --> 00:20:37,679
us the redshifts

455
00:20:41,590 --> 00:20:39,679
in this picture we on earth are sitting

456
00:20:44,310 --> 00:20:41,600
at the center of these two cones

457
00:20:44,789 --> 00:20:44,320
looking outwards into space and each one

458
00:20:48,549 --> 00:20:44,799
of those

459
00:20:50,390 --> 00:20:48,559
tiny white dots is a single galaxy

460
00:20:52,630 --> 00:20:50,400
what this image is showing us is that

461
00:20:53,430 --> 00:20:52,640
galaxies aren't randomly distributed in

462
00:20:55,830 --> 00:20:53,440
space

463
00:20:57,110 --> 00:20:55,840

they're organized into a beautiful if

464
00:20:59,669 --> 00:20:57,120
slightly creepy

465
00:21:00,870 --> 00:20:59,679
cosmic web made of strings of galaxies

466
00:21:04,710 --> 00:21:00,880
called filaments

467
00:21:06,950 --> 00:21:04,720
with empty spaces or voids between them

468
00:21:08,230 --> 00:21:06,960
now astrophysicists are a curious bunch

469
00:21:11,510 --> 00:21:08,240
and we want to know

470
00:21:14,070 --> 00:21:11,520
how does this structure come about so

471
00:21:15,750 --> 00:21:14,080
we build giant computer programs called

472
00:21:21,110 --> 00:21:15,760
simulations

473
00:21:24,710 --> 00:21:23,430
so yeah to explore we build these giant

474
00:21:26,230 --> 00:21:24,720
computer programs

475
00:21:28,149 --> 00:21:26,240
and let them predict what the universe

476
00:21:29,350 --> 00:21:28,159
should look like you can think of these

477
00:21:32,390 --> 00:21:29,360
simulations as

478
00:21:33,750 --> 00:21:32,400
a universe in a box they include all the

479
00:21:36,230 --> 00:21:33,760
physics we know

480
00:21:38,149 --> 00:21:36,240
gravity the way fluids move how stars

481
00:21:40,070 --> 00:21:38,159
and galaxies form and evolve

482
00:21:41,190 --> 00:21:40,080
and most importantly the presence of

483
00:21:44,710 --> 00:21:41,200
both regular

484
00:21:46,310 --> 00:21:44,720
and dark matter this image is a snapshot

485
00:21:48,630 --> 00:21:46,320
from one such simulation

486
00:21:49,510 --> 00:21:48,640
illustrious yellow dots represent

487
00:21:52,310 --> 00:21:49,520
galaxies

488
00:21:53,750 --> 00:21:52,320

the blue shows dark matter you can see

489
00:21:54,390 --> 00:21:53,760
the same structure of voids and

490
00:21:57,190 --> 00:21:54,400
filaments

491
00:21:58,710 --> 00:21:57,200
the same cosmic web emerge as in the

492
00:22:01,590 --> 00:21:58,720
real data

493
00:22:02,070 --> 00:22:01,600
uh to get to make this picture even more

494
00:22:03,430 --> 00:22:02,080
clear

495
00:22:06,870 --> 00:22:03,440
let's look at these two images side by

496
00:22:09,909 --> 00:22:09,029
on the left is the same image of the

497
00:22:12,310 --> 00:22:09,919
illustrious

498
00:22:13,750 --> 00:22:12,320
uh simulation i just showed you recolor

499
00:22:15,990 --> 00:22:13,760
to black and white

500
00:22:17,830 --> 00:22:16,000
the right is that same image of the

501
00:22:18,870 --> 00:22:17,840
cosmic web from the two degree field

502
00:22:21,350 --> 00:22:18,880
survey

503
00:22:23,590 --> 00:22:21,360
without dark matter the pattern of

504
00:22:24,310 --> 00:22:23,600
filaments and voids and simulations on

505
00:22:26,630 --> 00:22:24,320
the left

506
00:22:27,830 --> 00:22:26,640
would not match the observed reality of

507
00:22:29,510 --> 00:22:27,840
the cosmic web

508
00:22:31,110 --> 00:22:29,520
there would be too much empty space too

509
00:22:33,029 --> 00:22:31,120
many voids and the filaments would be

510
00:22:35,590 --> 00:22:33,039
too far apart

511
00:22:37,029 --> 00:22:35,600
dark matter is literally the scaffolding

512
00:22:40,070 --> 00:22:37,039
holding the universe together

513
00:22:41,669 --> 00:22:40,080

into this beautiful web all of these

514
00:22:43,830 --> 00:22:41,679
lines of evidence that we've discussed

515
00:22:47,510 --> 00:22:43,840
so cosmological simulations

516
00:22:50,789 --> 00:22:47,520
uh the way galaxy spins galaxy clusters

517
00:22:52,470 --> 00:22:50,799
and many others uh many other lines of

518
00:22:54,630 --> 00:22:52,480
evidence are telling us that we can't

519
00:22:58,070 --> 00:22:54,640
explain the observable universe

520
00:23:01,470 --> 00:22:58,080
without the existence of dark matter

521
00:23:02,710 --> 00:23:01,480
but what exactly is dark matter well

522
00:23:04,870 --> 00:23:02,720
[Music]

523
00:23:06,870 --> 00:23:04,880
our best guess right now is that dark

524
00:23:12,149 --> 00:23:06,880
matter is some sort of undiscovered

525
00:23:16,230 --> 00:23:13,909
many candidate particles have been

526
00:23:18,710 --> 00:23:16,240
proposed with exotic names like

527
00:23:20,950 --> 00:23:18,720
weakly interacting massive particles

528
00:23:24,070 --> 00:23:20,960
dark photons dark neutrons

529
00:23:25,190 --> 00:23:24,080
axions these weird unseen particles are

530
00:23:27,830 --> 00:23:25,200
collectively termed

531
00:23:29,590 --> 00:23:27,840
the dark sector and it's where we think

532
00:23:31,750 --> 00:23:29,600
dark matter is hiding

533
00:23:33,270 --> 00:23:31,760
dark matter could be any one of these or

534
00:23:34,710 --> 00:23:33,280
several of these or something else

535
00:23:36,630 --> 00:23:34,720
altogether

536
00:23:38,149 --> 00:23:36,640
experiments to detect dark matter

537
00:23:38,870 --> 00:23:38,159
particles are currently underway

538
00:23:41,029 --> 00:23:38,880

everywhere

539
00:23:43,110 --> 00:23:41,039
from the deepest underground mines to

540
00:23:43,830 --> 00:23:43,120
particle accelerators to satellites in

541
00:23:46,149 --> 00:23:43,840
orbit

542
00:23:47,110 --> 00:23:46,159
yet its exact nature continues to elude

543
00:23:49,029 --> 00:23:47,120
us

544
00:23:50,789 --> 00:23:49,039
dark matter is one of the great cosmic

545
00:23:59,430 --> 00:23:50,799
mysteries and just one of many

546
00:24:03,350 --> 00:24:01,269
very cool i'm sure there are some great

547
00:24:04,070 --> 00:24:03,360
questions out there uh thalia what are

548
00:24:05,750 --> 00:24:04,080
the people

549
00:24:07,190 --> 00:24:05,760
dark matter is always a hot topic people

550
00:24:09,020 --> 00:24:07,200
always want to know more about it

551
00:24:11,190 --> 00:24:09,030
i like asking today

552
00:24:13,669 --> 00:24:11,200
[Laughter]

553
00:24:14,390 --> 00:24:13,679
yeah so we have a lot of curious minds

554
00:24:15,830 --> 00:24:14,400
out there

555
00:24:18,230 --> 00:24:15,840
folks want to know a little bit more

556
00:24:24,870 --> 00:24:18,240
about dark matter so let's see

557
00:24:27,909 --> 00:24:26,070
all right well let's see if we can

558
00:24:30,470 --> 00:24:27,919
answer this question uh craig on

559
00:24:30,870 --> 00:24:30,480
facebook is asking have we measured the

560
00:24:34,230 --> 00:24:30,880
mass

561
00:24:37,430 --> 00:24:34,240
of dark matter so

562
00:24:40,149 --> 00:24:37,440
that's an excellent question and it's

563
00:24:41,909 --> 00:24:40,159

um it's essentially related to what sort

564
00:24:44,870 --> 00:24:41,919
of a particle could dark matter be

565
00:24:46,390 --> 00:24:44,880
if it even is a particle so we know that

566
00:24:49,510 --> 00:24:46,400
there has to be a certain

567
00:24:52,390 --> 00:24:49,520
amount of extra mass hidden from

568
00:24:52,789 --> 00:24:52,400
i in the universe like i said before

569
00:24:55,029 --> 00:24:52,799
about

570
00:24:56,149 --> 00:24:55,039
four-fifths of all gravitationally

571
00:24:58,710 --> 00:24:56,159
interacting matter

572
00:25:00,789 --> 00:24:58,720
but you could have massive and massive

573
00:25:02,070 --> 00:25:00,799
and massive quantities of an extremely

574
00:25:05,750 --> 00:25:02,080
light particle

575
00:25:09,029 --> 00:25:05,760
or somewhat a somewhat reduced quantity

576
00:25:12,230 --> 00:25:09,039
of a slightly heavier particle like

577
00:25:15,590 --> 00:25:12,240
weighing what dark matter is what a dark

578
00:25:20,789 --> 00:25:15,600
matter particle would be

579
00:25:23,909 --> 00:25:23,190
very cool so we'll talk more about nobel

580
00:25:26,470 --> 00:25:23,919
prizes

581
00:25:27,110 --> 00:25:26,480
and dark matter uh in just a little bit

582
00:25:29,510 --> 00:25:27,120
but we

583
00:25:30,630 --> 00:25:29,520
want to get to our our final speaker and

584
00:25:32,070 --> 00:25:30,640
then we'll bring everybody back and

585
00:25:33,430 --> 00:25:32,080
we'll do kind of a group discuss we'll

586
00:25:34,230 --> 00:25:33,440
get because a lot of these questions are

587
00:25:35,750 --> 00:25:34,240
asking

588
00:25:36,870 --> 00:25:35,760

we can get multiple answers from all of

589
00:25:38,390 --> 00:25:36,880
our speakers so it'd be great to get

590
00:25:41,029 --> 00:25:38,400
everyone involved in those

591
00:25:42,870 --> 00:25:41,039
uh but our final speaker an exoplanet

592
00:25:44,630 --> 00:25:42,880
scientist at nasa jpl

593
00:25:46,470 --> 00:25:44,640
she investigates the atmospheric

594
00:25:49,029 --> 00:25:46,480
circulation or

595
00:25:51,110 --> 00:25:49,039
weather of exoplanet atmospheres and

596
00:25:53,190 --> 00:25:51,120
what we can learn about these processes

597
00:25:55,430 --> 00:25:53,200
from telescopic observations

598
00:25:56,470 --> 00:25:55,440
here to depict the menace of weather on

599
00:26:00,390 --> 00:25:56,480
exoplanets

600
00:26:06,149 --> 00:26:00,400
is dr tiffany kataria hi tiffany

601
00:26:12,070 --> 00:26:09,750
i love it so let me the better to see

602
00:26:13,510 --> 00:26:12,080
these posters i'm gonna take my glasses

603
00:26:16,390 --> 00:26:13,520
off here for now

604
00:26:17,269 --> 00:26:16,400
um so uh this evening we've already

605
00:26:19,029 --> 00:26:17,279
talked about uh

606
00:26:20,549 --> 00:26:19,039
scary collisions we've talked about

607
00:26:22,230 --> 00:26:20,559
scary dark matter

608
00:26:24,710 --> 00:26:22,240
and so i wanted to close it out by

609
00:26:27,029 --> 00:26:24,720
talking about scary planets

610
00:26:28,870 --> 00:26:27,039
um these posters that have been uh that

611
00:26:30,710 --> 00:26:28,880
were developed just a year ago

612
00:26:32,470 --> 00:26:30,720
that i helped inform on um they

613
00:26:34,390 --> 00:26:32,480

certainly look scary

614
00:26:36,710 --> 00:26:34,400
but i want to talk a bit about what

615
00:26:38,470 --> 00:26:36,720
science actually makes these posters so

616
00:26:39,830 --> 00:26:38,480
scary

617
00:26:41,830 --> 00:26:39,840
so we're going to walk through all three

618
00:26:42,870 --> 00:26:41,840
that exist uh out in the world right now

619
00:26:44,549 --> 00:26:42,880
so you can go home and

620
00:26:46,950 --> 00:26:44,559
you can download it from the comfort of

621
00:26:47,990 --> 00:26:46,960
your homes so the first one here is the

622
00:26:52,390 --> 00:26:48,000
reigns of terror

623
00:26:55,350 --> 00:26:52,400
on hd 189 733b rolls off the tongue

624
00:26:56,710 --> 00:26:55,360
this is a planet uh called a hot jupiter

625
00:26:58,230 --> 00:26:56,720
and so the reason it's called a hot

626
00:26:59,830 --> 00:26:58,240
jupiter it's because it's roughly

627
00:27:01,990 --> 00:26:59,840
jupiter in size

628
00:27:03,669 --> 00:27:02,000
and it's hot because of its temperature

629
00:27:05,750 --> 00:27:03,679
it orbits its parent star

630
00:27:07,990 --> 00:27:05,760
roughly every two days so it's actually

631
00:27:08,470 --> 00:27:08,000
ten times closer than mercury orbits our

632
00:27:10,070 --> 00:27:08,480
sun

633
00:27:11,990 --> 00:27:10,080
so that means it experiences

634
00:27:12,870 --> 00:27:12,000
temperatures of something like sixteen

635
00:27:16,070 --> 00:27:12,880
hundred

636
00:27:17,669 --> 00:27:16,080
fahrenheit so we think earth is hot

637
00:27:20,789 --> 00:27:17,679
certainly in l.a it's hot but

638
00:27:22,549 --> 00:27:20,799

this is a hot uh environment

639
00:27:24,389 --> 00:27:22,559
and so this planet was actually found

640
00:27:26,149 --> 00:27:24,399
using the transit method

641
00:27:27,990 --> 00:27:26,159
and so this is a common technique used

642
00:27:29,990 --> 00:27:28,000
to use to find exoplanets

643
00:27:31,350 --> 00:27:30,000
um and so you're actually staring at the

644
00:27:34,230 --> 00:27:31,360
star over time

645
00:27:35,110 --> 00:27:34,240
and when you see uh the light dimming

646
00:27:37,110 --> 00:27:35,120
over time

647
00:27:39,110 --> 00:27:37,120
you can infer that a planet is there so

648
00:27:40,950 --> 00:27:39,120
if you're observing as it transits you

649
00:27:42,549 --> 00:27:40,960
can infer that the planet's there

650
00:27:43,990 --> 00:27:42,559
so a bigger planet will block out more

651
00:27:45,190 --> 00:27:44,000
light a smaller planet will block out

652
00:27:48,070 --> 00:27:45,200
less light so that's how we know that

653
00:27:50,310 --> 00:27:48,080
this is a jupiter-sized planet

654
00:27:52,230 --> 00:27:50,320
so this planet is particularly scary

655
00:27:54,710 --> 00:27:52,240
because of these rains of terror

656
00:27:55,430 --> 00:27:54,720
and so given these high temperatures the

657
00:27:58,470 --> 00:27:55,440
planet is

658
00:28:00,549 --> 00:27:58,480
is so hot that the rocks and minerals we

659
00:28:02,389 --> 00:28:00,559
find on earth are actually

660
00:28:03,750 --> 00:28:02,399
would vaporize in these atmospheres and

661
00:28:06,630 --> 00:28:03,760
form clouds and so

662
00:28:07,350 --> 00:28:06,640
we can think of um sands or glass uh

663
00:28:09,430 --> 00:28:07,360

silicates

664
00:28:11,110 --> 00:28:09,440
is commonly what are these these clouds

665
00:28:12,149 --> 00:28:11,120
are made of and so that's why we call

666
00:28:14,230 --> 00:28:12,159
them here clouds

667
00:28:16,149 --> 00:28:14,240
clouds of glass and that's actually what

668
00:28:17,750 --> 00:28:16,159
makes um their observations that

669
00:28:20,149 --> 00:28:17,760
actually suggest that this planet's

670
00:28:22,710 --> 00:28:20,159
atmosphere is blue

671
00:28:23,430 --> 00:28:22,720
that's due to that glass not only does

672
00:28:25,669 --> 00:28:23,440
this glass

673
00:28:27,830 --> 00:28:25,679
appear in the sky um but it's actually

674
00:28:31,350 --> 00:28:27,840
being blown about by these really uh

675
00:28:33,430 --> 00:28:31,360
howling strong winds of roughly 5

676
00:28:35,350 --> 00:28:33,440
000 miles per hour and that's again due

677
00:28:36,149 --> 00:28:35,360
to how close the planet is to the star

678
00:28:37,990 --> 00:28:36,159
it actually

679
00:28:40,070 --> 00:28:38,000
has a permanent day side and a permanent

680
00:28:42,870 --> 00:28:40,080
night side which is what this this

681
00:28:45,110 --> 00:28:42,880
artist conception is showing you here so

682
00:28:47,430 --> 00:28:45,120
given that geometry you're actually

683
00:28:49,029 --> 00:28:47,440
experienced this planet experiences um

684
00:28:50,710 --> 00:28:49,039
these very very strong ones so

685
00:28:52,389 --> 00:28:50,720
definitely not a planet you'd want to go

686
00:28:54,630 --> 00:28:52,399
visit

687
00:28:55,990 --> 00:28:54,640
so let's go to the next uh slide and the

688
00:28:59,430 --> 00:28:56,000

next planet

689
00:29:02,470 --> 00:28:59,440
so this one is flares of fury on au

690
00:29:04,789 --> 00:29:02,480
microscopy or au mcb

691
00:29:07,590 --> 00:29:04,799
um this planet is roughly neptune in

692
00:29:10,549 --> 00:29:07,600
size um it orbits its stars every uh

693
00:29:12,710 --> 00:29:10,559
eight days roughly the system itself is

694
00:29:14,070 --> 00:29:12,720
actually only 32 light years away so

695
00:29:14,950 --> 00:29:14,080
it's actually one of the closest systems

696
00:29:17,990 --> 00:29:14,960
to us so

697
00:29:18,310 --> 00:29:18,000
frighteningly close one might say um and

698
00:29:21,029 --> 00:29:18,320
this

699
00:29:22,950 --> 00:29:21,039
uh system is particularly scary because

700
00:29:25,269 --> 00:29:22,960
um it orbits the the star

701
00:29:25,990 --> 00:29:25,279
or the rather the planet orbits a red

702
00:29:28,070 --> 00:29:26,000
dwarf star

703
00:29:29,430 --> 00:29:28,080
that's what the the type of this star

704
00:29:32,549 --> 00:29:29,440
and so a red dwarf

705
00:29:34,710 --> 00:29:32,559
is about half as cool as our sun and

706
00:29:36,149 --> 00:29:34,720
what's notable about it is uh

707
00:29:38,389 --> 00:29:36,159
given how young the system is it's

708
00:29:40,630 --> 00:29:38,399
actually undergoing quite a lot of

709
00:29:41,750 --> 00:29:40,640
magnetic activity or radiation so it's

710
00:29:43,909 --> 00:29:41,760
emitting these

711
00:29:45,110 --> 00:29:43,919
this high amount of radiation that uh

712
00:29:47,669 --> 00:29:45,120
then the planet

713
00:29:48,310 --> 00:29:47,679

is encountering and so again a very

714
00:29:51,110 --> 00:29:48,320
scary

715
00:29:53,110 --> 00:29:51,120
um uh environment to take place in um

716
00:29:55,110 --> 00:29:53,120
not only this but the system is also

717
00:29:57,110 --> 00:29:55,120
known to have a debris disk

718
00:29:59,350 --> 00:29:57,120
so viewed from earth we actually see an

719
00:30:00,149 --> 00:29:59,360
edge on and so a debris disk is

720
00:30:02,789 --> 00:30:00,159
basically what

721
00:30:03,510 --> 00:30:02,799
a disk full of debris in this case it's

722
00:30:06,230 --> 00:30:03,520
dust

723
00:30:07,909 --> 00:30:06,240
and so these are actually ideal

724
00:30:09,430 --> 00:30:07,919
environments to look for planets because

725
00:30:10,789 --> 00:30:09,440
you've got all this material making

726
00:30:14,230 --> 00:30:10,799
those planets and so

727
00:30:15,750 --> 00:30:14,240
this was kind of a nice um confirmation

728
00:30:16,789 --> 00:30:15,760
of what was always suspected that you

729
00:30:20,070 --> 00:30:16,799
know these are good

730
00:30:21,350 --> 00:30:20,080
places to search uh for planets and this

731
00:30:24,549 --> 00:30:21,360
particular one was found

732
00:30:25,990 --> 00:30:24,559
using the test the transiting exoplanet

733
00:30:29,029 --> 00:30:26,000
survey satellite so this is an

734
00:30:30,710 --> 00:30:29,039
all-sky transit survey but yeah another

735
00:30:32,470 --> 00:30:30,720
another scary

736
00:30:33,990 --> 00:30:32,480
scary planet that you wouldn't want to

737
00:30:36,789 --> 00:30:34,000
go visit

738
00:30:37,510 --> 00:30:36,799

and finally the last slide uh our third

739
00:30:39,510 --> 00:30:37,520
poster

740
00:30:41,269 --> 00:30:39,520
um this one i would say is the scariest

741
00:30:44,870 --> 00:30:41,279
of all you know this one was really

742
00:30:46,389 --> 00:30:44,880
made for the series um this is a pulsar

743
00:30:47,909 --> 00:30:46,399
planet system they're actually three

744
00:30:49,430 --> 00:30:47,919
planets in this system

745
00:30:51,830 --> 00:30:49,440
um it's actually one of the first

746
00:30:55,510 --> 00:30:51,840
exoplanet systems ever discovered

747
00:30:58,710 --> 00:30:55,520
um this psr uh b1257 again

748
00:31:01,029 --> 00:30:58,720
rolls off the tongue um a pulsar

749
00:31:03,350 --> 00:31:01,039
is a rapidly rotating star that emits a

750
00:31:05,110 --> 00:31:03,360
ton of electromagnetic radiation

751
00:31:06,630 --> 00:31:05,120
out of its poles that's what this image

752
00:31:09,029 --> 00:31:06,640
and the poster is showing you

753
00:31:11,269 --> 00:31:09,039
and so um it's a pulse it's called a

754
00:31:14,230 --> 00:31:11,279
pulsar because it emits that radiation

755
00:31:14,549 --> 00:31:14,240
um at millisecond pulses roughly and so

756
00:31:18,870 --> 00:31:14,559
you

757
00:31:20,630 --> 00:31:18,880
electromagnetic radiation is being

758
00:31:23,669 --> 00:31:20,640
emitted and viewed towards earth

759
00:31:26,549 --> 00:31:23,679
and so any anomaly any scary deviation

760
00:31:27,990 --> 00:31:26,559
from that uh pulse uh tells you that

761
00:31:29,190 --> 00:31:28,000
there might be a planet there and so in

762
00:31:29,830 --> 00:31:29,200
this case there are actually three

763
00:31:31,990 --> 00:31:29,840

planets

764
00:31:34,149 --> 00:31:32,000
um in this system i should start by

765
00:31:34,789 --> 00:31:34,159
saying the the star itself is called

766
00:31:37,909 --> 00:31:34,799
lich

767
00:31:39,669 --> 00:31:37,919
wikipedia you'll see it's an

768
00:31:41,509 --> 00:31:39,679
undead creature that's known for

769
00:31:42,630 --> 00:31:41,519
controlling other undead creatures by

770
00:31:45,269 --> 00:31:42,640
magic so again

771
00:31:47,269 --> 00:31:45,279
totally totally scary to begin with um

772
00:31:49,750 --> 00:31:47,279
the three planets are actually named

773
00:31:51,990 --> 00:31:49,760
also uh scary creatures uh draugr

774
00:31:54,870 --> 00:31:52,000
poltergeist and phobitour

775
00:31:56,789 --> 00:31:54,880
dragger the planet a is actually half

776
00:31:58,470 --> 00:31:56,799
the mass of earth's moon

777
00:32:01,350 --> 00:31:58,480
so really i would say this is the

778
00:32:03,509 --> 00:32:01,360
scariest of all all planet systems

779
00:32:04,950 --> 00:32:03,519
um it's really yeah made for galaxy of

780
00:32:07,190 --> 00:32:04,960
horse poster

781
00:32:11,669 --> 00:32:07,200
so yeah with that i'll uh take some

782
00:32:14,950 --> 00:32:14,149
all right tiffany so there are tons of

783
00:32:19,029 --> 00:32:14,960
questions that

784
00:32:24,310 --> 00:32:21,750
out there yeah there are there are a lot

785
00:32:26,789 --> 00:32:24,320
of scary worlds out there um but allison

786
00:32:30,230 --> 00:32:26,799
on facebook wants to know how on earth

787
00:32:32,549 --> 00:32:30,240
did those planets survive a supernova

788
00:32:33,990 --> 00:32:32,559

that's a great question um and i mean

789
00:32:35,269 --> 00:32:34,000
the the answer at the end of the day is

790
00:32:37,110 --> 00:32:35,279
we don't really know i think there are a

791
00:32:38,630 --> 00:32:37,120
couple theories being kicked about um

792
00:32:39,750 --> 00:32:38,640
one that i saw that was being kicked

793
00:32:41,669 --> 00:32:39,760
about was that maybe

794
00:32:43,430 --> 00:32:41,679
these planets formed after the supernova

795
00:32:44,070 --> 00:32:43,440
maybe there was a second stage of planet

796
00:32:46,470 --> 00:32:44,080
formation

797
00:32:47,750 --> 00:32:46,480
after these two white dwarfs merged and

798
00:32:49,430 --> 00:32:47,760
formed those planets

799
00:32:50,789 --> 00:32:49,440
but there are any number of scenarios

800
00:32:51,909 --> 00:32:50,799
that maybe could have produced those

801
00:32:55,990 --> 00:32:51,919
those planets

802
00:32:58,789 --> 00:32:56,000
yeah all right and dan

803
00:33:01,350 --> 00:32:58,799
on facebook would like to know uh the

804
00:33:01,909 --> 00:33:01,360
hot jupiters are those mostly gas do

805
00:33:04,630 --> 00:33:01,919
they have

806
00:33:06,389 --> 00:33:04,640
any um you know terrestrial components

807
00:33:09,269 --> 00:33:06,399
to it

808
00:33:10,070 --> 00:33:09,279
so yeah given that it's a jupiter a hot

809
00:33:12,149 --> 00:33:10,080
jupiter

810
00:33:14,470 --> 00:33:12,159
it's mostly mostly gas hydrogen and

811
00:33:16,630 --> 00:33:14,480
helium gas there's probably some sort of

812
00:33:18,950 --> 00:33:16,640
core there that might be made of rock

813
00:33:19,830 --> 00:33:18,960

but we can really only see the the

814
00:33:22,070 --> 00:33:19,840
atmosphere

815
00:33:23,990 --> 00:33:22,080
so but any inference we're really making

816
00:33:25,430 --> 00:33:24,000
about these faraway systems are based

817
00:33:26,070 --> 00:33:25,440
off of what we know within our own solar

818
00:33:27,509 --> 00:33:26,080
system

819
00:33:30,710 --> 00:33:27,519
so the better we know jupiter the better

820
00:33:32,630 --> 00:33:30,720
we can understand hot shooters

821
00:33:33,830 --> 00:33:32,640
all right let's bring everybody back in

822
00:33:36,470 --> 00:33:33,840
here um

823
00:33:37,269 --> 00:33:36,480
all of our speakers are brilliant and

824
00:33:39,590 --> 00:33:37,279
can talk about

825
00:33:40,870 --> 00:33:39,600
many different topics um tonight i asked

826
00:33:41,990 --> 00:33:40,880
them kind of all to pick something that

827
00:33:43,190 --> 00:33:42,000
they really wanted

828
00:33:45,110 --> 00:33:43,200
felt passionate about and wanted to talk

829
00:33:46,630 --> 00:33:45,120
about but we're going to open it up

830
00:33:49,029 --> 00:33:46,640
because some of your questions

831
00:33:50,470 --> 00:33:49,039
may have an answer from every one of our

832
00:33:52,470 --> 00:33:50,480
speakers so

833
00:33:53,750 --> 00:33:52,480
philia it just seems like everybody's

834
00:33:54,630 --> 00:33:53,760
asking a lot of questions out there

835
00:33:56,149 --> 00:33:54,640
today what what

836
00:34:01,190 --> 00:33:56,159
what let's keep hearing what they're

837
00:34:05,029 --> 00:34:03,990
yeah so we have tons of great questions

838
00:34:08,470 --> 00:34:05,039

um

839
00:34:10,310 --> 00:34:08,480
so let's see uh so cody wants to know

840
00:34:11,669 --> 00:34:10,320
i think going back to the exoplanets

841
00:34:13,430 --> 00:34:11,679
cody on youtube asks

842
00:34:18,550 --> 00:34:13,440
is there really a planet that rains

843
00:34:25,030 --> 00:34:21,909
yes the answer is yes um

844
00:34:26,230 --> 00:34:25,040
you know so this particular uh system

845
00:34:28,310 --> 00:34:26,240
actually is one of the best

846
00:34:28,710 --> 00:34:28,320
characterized um hot jupiters we know

847
00:34:31,190 --> 00:34:28,720
about

848
00:34:33,109 --> 00:34:31,200
um that is to say a lot of telescopes

849
00:34:35,030 --> 00:34:33,119
have been observing this system and so

850
00:34:36,710 --> 00:34:35,040
we understand quite a lot about

851
00:34:38,550 --> 00:34:36,720
its atmospheric properties so we know

852
00:34:40,869 --> 00:34:38,560
that there's water in the atmosphere

853
00:34:42,389 --> 00:34:40,879
um we know uh we have a good handle on

854
00:34:44,389 --> 00:34:42,399
how hot it is and so

855
00:34:46,149 --> 00:34:44,399
um and and as i mentioned earlier you

856
00:34:47,829 --> 00:34:46,159
know the this blue color

857
00:34:49,430 --> 00:34:47,839
this actually isn't really an artist's

858
00:34:51,270 --> 00:34:49,440
conception it's actually derived from

859
00:34:54,069 --> 00:34:51,280
real science and so in this case

860
00:34:54,389 --> 00:34:54,079
um given how you know the the particles

861
00:34:57,990 --> 00:34:54,399
in

862
00:34:59,670 --> 00:34:58,000
actually makes it

863
00:35:01,510 --> 00:34:59,680

um blue to the naked eye so it was

864
00:35:05,190 --> 00:35:01,520
observed to be blue based off of

865
00:35:07,510 --> 00:35:05,200
observations and so uh

866
00:35:09,270 --> 00:35:07,520
yeah so so given that given the

867
00:35:11,510 --> 00:35:09,280
simulations that i run

868
00:35:13,109 --> 00:35:11,520
to compute the 3d winds in the

869
00:35:15,670 --> 00:35:13,119
atmosphere

870
00:35:16,790 --> 00:35:15,680
all simulations that i have run and

871
00:35:18,630 --> 00:35:16,800
other um

872
00:35:20,790 --> 00:35:18,640
uh exoplanet scientists have run show

873
00:35:23,430 --> 00:35:20,800
that these winds are are very likely

874
00:35:24,790 --> 00:35:23,440
um and in fact they're actually um other

875
00:35:26,230 --> 00:35:24,800
observations that have made direct

876
00:35:27,589 --> 00:35:26,240
measurements of those winds

877
00:35:30,310 --> 00:35:27,599
so you can measure essentially the

878
00:35:33,430 --> 00:35:30,320
doppler shift of a

879
00:35:34,870 --> 00:35:33,440
molecular line so if you look at water

880
00:35:36,550 --> 00:35:34,880
in the atmosphere and you measure the

881
00:35:38,950 --> 00:35:36,560
doppler shift of that

882
00:35:40,550 --> 00:35:38,960
molecule you can actually derive what

883
00:35:42,470 --> 00:35:40,560
the wind speed or the rotation

884
00:35:43,829 --> 00:35:42,480
of the planet is so it's all very cool

885
00:35:46,870 --> 00:35:43,839
all very

886
00:35:47,670 --> 00:35:46,880
sophisticated analyses that can lead to

887
00:35:53,030 --> 00:35:47,680
these really

888
00:35:57,109 --> 00:35:56,069

all right thank you for that so we heard

889
00:35:59,750 --> 00:35:57,119
earlier

890
00:36:02,630 --> 00:35:59,760
that the universe is expanding but pete

891
00:36:06,550 --> 00:36:02,640
on facebook asks a very great question

892
00:36:08,630 --> 00:36:06,560
what is the universe expanding into

893
00:36:13,030 --> 00:36:08,640
and i don't know if dan or jacqueline

894
00:36:16,230 --> 00:36:13,040
you want to take that one one

895
00:36:19,829 --> 00:36:16,240
all right let's do this so that is an

896
00:36:20,950 --> 00:36:19,839
awesome question um and i think you

897
00:36:22,550 --> 00:36:20,960
almost have

898
00:36:24,230 --> 00:36:22,560
the best answer i could think of was a

899
00:36:27,670 --> 00:36:24,240
philosophical one

900
00:36:30,390 --> 00:36:27,680
so if the universe is all that is

901
00:36:31,510 --> 00:36:30,400
what is does it make sense to think

902
00:36:34,790 --> 00:36:31,520
about distances

903
00:36:36,630 --> 00:36:34,800
outside of it uh i i think perhaps

904
00:36:38,150 --> 00:36:36,640
bringing it back down to earth a little

905
00:36:41,430 --> 00:36:38,160
bit figuratively

906
00:36:44,069 --> 00:36:41,440
um it's unknowable our laws of physics

907
00:36:46,230 --> 00:36:44,079
are defined for the universe that we see

908
00:36:47,270 --> 00:36:46,240
anything outside of that universe we

909
00:36:49,990 --> 00:36:47,280
don't have the means

910
00:36:51,910 --> 00:36:50,000
to formulate theories or test theories

911
00:36:55,030 --> 00:36:51,920
we can only speculate

912
00:36:55,990 --> 00:36:55,040
so the answer to your question which is

913
00:36:59,030 --> 00:36:56,000

a very good one

914
00:37:01,829 --> 00:36:59,040
is uh unclear and i don't know if we'll

915
00:37:05,109 --> 00:37:03,430
the fear of the other that was a very

916
00:37:09,589 --> 00:37:05,119
great question

917
00:37:12,950 --> 00:37:09,599
melissa on

918
00:37:15,430 --> 00:37:12,960
youtube wants to know are there multiple

919
00:37:18,310 --> 00:37:15,440
universes i don't know who wants to take

920
00:37:21,990 --> 00:37:21,270
i mean why not there so there's a bunch

921
00:37:24,550 --> 00:37:22,000
of uh

922
00:37:25,910 --> 00:37:24,560
there are a bunch of theories uh a bunch

923
00:37:29,430 --> 00:37:25,920
of cosmologies

924
00:37:32,150 --> 00:37:29,440
that suggest that uh we do have uni

925
00:37:32,710 --> 00:37:32,160
we do have multiverses that our universe

926
00:37:35,990 --> 00:37:32,720
is

927
00:37:39,349 --> 00:37:36,000
a bubble and some giant foam of

928
00:37:41,510 --> 00:37:39,359
many such universes um

929
00:37:43,589 --> 00:37:41,520
uh i think we're still looking for

930
00:37:46,150 --> 00:37:43,599
experimental predictions of those

931
00:37:48,150 --> 00:37:46,160
of those theories um and once we have

932
00:37:51,589 --> 00:37:48,160
experimental predictions we can start

933
00:37:52,950 --> 00:37:51,599
to assess whether or not this is true

934
00:37:55,030 --> 00:37:52,960
it's certainly a really intriguing

935
00:37:57,589 --> 00:37:55,040
possibility i like the notion of a foam

936
00:37:59,030 --> 00:37:57,599
of universes

937
00:38:01,109 --> 00:37:59,040
there was a prediction that you might

938
00:38:02,790 --> 00:38:01,119

get this ring in the cosmic microwave

939
00:38:05,270 --> 00:38:02,800
background radiation

940
00:38:07,990 --> 00:38:05,280
of different temperature as two

941
00:38:10,790 --> 00:38:08,000
multiverses collided together

942
00:38:11,190 --> 00:38:10,800
and there was a paper i'm not sure how

943
00:38:13,829 --> 00:38:11,200
many

944
00:38:14,710 --> 00:38:13,839
people really think that's the end-all

945
00:38:16,550 --> 00:38:14,720
answer but

946
00:38:18,150 --> 00:38:16,560
there was a claim of maybe seeing a ring

947
00:38:19,670 --> 00:38:18,160
that could be from that

948
00:38:27,829 --> 00:38:19,680
or it could just be a statistical

949
00:38:31,430 --> 00:38:29,589
all right so we have some other great

950
00:38:33,670 --> 00:38:31,440
questions in the chat

951
00:38:35,349 --> 00:38:33,680
a question that has come up twice now uh

952
00:38:37,910 --> 00:38:35,359
kashmi on youtube

953
00:38:40,470 --> 00:38:37,920
asks is dark matter present in black

954
00:38:46,950 --> 00:38:43,910
um wow so many good questions uh

955
00:38:49,750 --> 00:38:46,960
so i think how

956
00:38:50,230 --> 00:38:49,760
how would i think about this so at the

957
00:38:53,510 --> 00:38:50,240
very

958
00:38:56,069 --> 00:38:53,520
center of a black hole uh you have

959
00:38:56,790 --> 00:38:56,079
you have a singularity right you have an

960
00:38:59,270 --> 00:38:56,800
area of

961
00:39:00,710 --> 00:38:59,280
effectively infinite density or nearly

962
00:39:03,349 --> 00:39:00,720
infinite density

963
00:39:04,870 --> 00:39:03,359

and i think at that point i don't know

964
00:39:06,870 --> 00:39:04,880
if you can talk about

965
00:39:08,790 --> 00:39:06,880
dark matter as dark matter or regular

966
00:39:11,910 --> 00:39:08,800
matter as regular matter

967
00:39:14,630 --> 00:39:11,920
certainly say dark matter bound

968
00:39:16,390 --> 00:39:14,640
to to gas or stars or whatever that get

969
00:39:18,790 --> 00:39:16,400
pulled into a black hole

970
00:39:20,550 --> 00:39:18,800
the dark matter you know if it is if

971
00:39:22,630 --> 00:39:20,560
dark matter is indeed a particle

972
00:39:23,750 --> 00:39:22,640
those particles will get accreted into

973
00:39:27,030 --> 00:39:23,760
the black hole

974
00:39:31,589 --> 00:39:27,040
same as anything else so i suppose the

975
00:39:35,589 --> 00:39:33,910
all right and we have some more really

976
00:39:38,710 --> 00:39:35,599
great questions in the chat

977
00:39:41,190 --> 00:39:38,720
uh let's see cody on facebook asks

978
00:39:45,109 --> 00:39:41,200
what evidence is the multiverse theory

979
00:39:53,030 --> 00:39:48,870
um dan you want to take that one

980
00:39:56,230 --> 00:39:53,040
sure i'll start you can jump in but um

981
00:39:58,069 --> 00:39:56,240
there are you know uh

982
00:39:59,430 --> 00:39:58,079
we measure things in our universe like

983
00:40:01,349 --> 00:39:59,440
the mass of the proton

984
00:40:03,910 --> 00:40:01,359
the charge of the electron there's

985
00:40:07,109 --> 00:40:03,920
various parameters that we can't

986
00:40:07,829 --> 00:40:07,119
predict with current physics and so one

987
00:40:11,190 --> 00:40:07,839
thought is that

988
00:40:11,990 --> 00:40:11,200

maybe when the universe and the big bang

989
00:40:14,150 --> 00:40:12,000
happens

990
00:40:15,030 --> 00:40:14,160
kind of dice get rolled and those

991
00:40:17,750 --> 00:40:15,040
parameters

992
00:40:19,750 --> 00:40:17,760
get set to some value maybe even how

993
00:40:22,550 --> 00:40:19,760
many dimensions the universe is

994
00:40:24,150 --> 00:40:22,560
is one of those parameters and if you as

995
00:40:26,470 --> 00:40:24,160
soon as you start thinking about that

996
00:40:28,230 --> 00:40:26,480
as a solution for trying to understand

997
00:40:29,910 --> 00:40:28,240
what these parameters are

998
00:40:32,230 --> 00:40:29,920
then it naturally leads to the idea well

999
00:40:33,750 --> 00:40:32,240
maybe there are other dice being rolled

1000
00:40:35,510 --> 00:40:33,760
with other parameters

1001
00:40:37,670 --> 00:40:35,520
happening and so there might be a whole

1002
00:40:40,790 --> 00:40:37,680
other set of multiverses

1003
00:40:42,790 --> 00:40:40,800
as jacqueline hit on though this is

1004
00:40:44,710 --> 00:40:42,800
you know sort of balancing it is whether

1005
00:40:45,589 --> 00:40:44,720
it's science where there's a theory with

1006
00:40:48,550 --> 00:40:45,599
a predictive

1007
00:40:49,190 --> 00:40:48,560
predictable hypothesis is unclear it

1008
00:40:51,430 --> 00:40:49,200
might be more

1009
00:40:55,510 --> 00:40:51,440
philosophy and not have testable

1010
00:40:59,670 --> 00:40:58,550
all right very interesting um i think i

1011
00:41:02,710 --> 00:40:59,680
have a question for

1012
00:41:04,950 --> 00:41:02,720
tiffany mk3gtx on youtube

1013
00:41:07,030 --> 00:41:04,960

asks does the number of stars in the

1014
00:41:09,510 --> 00:41:07,040
system affect how many planets are

1015
00:41:11,750 --> 00:41:09,520
formed and do binary star systems have

1016
00:41:14,230 --> 00:41:11,760
more planets

1017
00:41:16,230 --> 00:41:14,240
that is a great question um so i i

1018
00:41:19,270 --> 00:41:16,240
should start by saying that we do

1019
00:41:20,230 --> 00:41:19,280
maybe mk knows this already that binary

1020
00:41:23,030 --> 00:41:20,240
star

1021
00:41:25,030 --> 00:41:23,040
planets systems do exist kepler the

1022
00:41:27,109 --> 00:41:25,040
kepler space telescope has found some

1023
00:41:29,270 --> 00:41:27,119
i think uh there's anticipated to be

1024
00:41:32,630 --> 00:41:29,280
more um with with tests and other

1025
00:41:34,309 --> 00:41:32,640
future surveys for exoplanets um so

1026
00:41:37,829 --> 00:41:34,319
let's see that was a multi-pronged

1027
00:41:40,069 --> 00:41:37,839
um question so do more uh

1028
00:41:41,990 --> 00:41:40,079
are more planets expected around around

1029
00:41:43,829 --> 00:41:42,000
binary systems so that was that was one

1030
00:41:45,829 --> 00:41:43,839
part of the question right

1031
00:41:48,230 --> 00:41:45,839
yeah so the first part is does the

1032
00:41:49,270 --> 00:41:48,240
number of stars in the system affect how

1033
00:41:52,790 --> 00:41:49,280
many planets are

1034
00:41:55,750 --> 00:41:52,800
formed yeah yes so so i

1035
00:41:56,550 --> 00:41:55,760
i think so yes so there have been um a

1036
00:41:59,270 --> 00:41:56,560
number of

1037
00:41:59,990 --> 00:41:59,280
um simulations of the orbital dynamics

1038
00:42:02,309 --> 00:42:00,000

of how

1039
00:42:04,069 --> 00:42:02,319
um planets and you know multiple stars

1040
00:42:07,589 --> 00:42:04,079
would interact and basically

1041
00:42:09,190 --> 00:42:07,599
um when there are two stars present that

1042
00:42:10,630 --> 00:42:09,200
means you're dealing with a three-body

1043
00:42:11,910 --> 00:42:10,640
system and that creates a lot more

1044
00:42:13,910 --> 00:42:11,920
instability and so

1045
00:42:15,910 --> 00:42:13,920
in a lot more cases you might expect

1046
00:42:17,109 --> 00:42:15,920
some planets to be actually just ejected

1047
00:42:19,910 --> 00:42:17,119
from the system

1048
00:42:21,750 --> 00:42:19,920
so just completely kicked out and so the

1049
00:42:22,230 --> 00:42:21,760
system has to be really stable to be

1050
00:42:25,990 --> 00:42:22,240
actual

1051
00:42:27,510 --> 00:42:26,000
to over um the long time period such

1052
00:42:29,030 --> 00:42:27,520
that the planet can survive

1053
00:42:31,190 --> 00:42:29,040
and you know gain an atmosphere and do

1054
00:42:32,630 --> 00:42:31,200
all those other things and so

1055
00:42:34,550 --> 00:42:32,640
you know given the pro those

1056
00:42:36,309 --> 00:42:34,560
probabilities it's it's perhaps less

1057
00:42:38,230 --> 00:42:36,319
likely that you know multiple planets

1058
00:42:39,270 --> 00:42:38,240
would exist around a binary star system

1059
00:42:40,069 --> 00:42:39,280
that's not to say that there are

1060
00:42:42,870 --> 00:42:40,079
probably

1061
00:42:44,950 --> 00:42:42,880
situations where that could happen um

1062
00:42:47,270 --> 00:42:44,960
but it's it's far less likely

1063
00:42:48,230 --> 00:42:47,280

um the second part was uh whether or not

1064
00:42:50,470 --> 00:42:48,240
there would be

1065
00:42:51,430 --> 00:42:50,480
um sorry can you repeat the second part

1066
00:42:55,589 --> 00:42:51,440
of the question

1067
00:42:57,270 --> 00:42:55,599
yeah sure uh so if binary star systems

1068
00:42:59,990 --> 00:42:57,280
have more planets

1069
00:43:01,270 --> 00:43:00,000
than i guess single star system than

1070
00:43:04,950 --> 00:43:01,280
single star systems

1071
00:43:08,950 --> 00:43:04,960
um i think

1072
00:43:09,510 --> 00:43:08,960
the answer you know i i don't know if we

1073
00:43:12,630 --> 00:43:09,520
we know

1074
00:43:14,710 --> 00:43:12,640
quite quite yet um i think you know tess

1075
00:43:15,990 --> 00:43:14,720
this all sky survey will really serve to

1076
00:43:17,990 --> 00:43:16,000
answer a lot of those um

1077
00:43:19,829 --> 00:43:18,000
questions i mean so much of what we've

1078
00:43:21,510 --> 00:43:19,839
um done for transit science

1079
00:43:23,190 --> 00:43:21,520
you know that's uh kind of where i'm

1080
00:43:24,470 --> 00:43:23,200
thinking has been for single star

1081
00:43:26,309 --> 00:43:24,480
systems um

1082
00:43:27,829 --> 00:43:26,319
and so i think you know the more

1083
00:43:28,550 --> 00:43:27,839
complete we have of the survey the

1084
00:43:32,230 --> 00:43:28,560
better we'll know

1085
00:43:35,589 --> 00:43:34,870
all right great let's see ian on

1086
00:43:38,790 --> 00:43:35,599
facebook

1087
00:43:41,270 --> 00:43:38,800
asks is it possible that dark energy is

1088
00:43:42,150 --> 00:43:41,280

caused by white holes expanding space

1089
00:43:45,109 --> 00:43:42,160
time without

1090
00:43:47,589 --> 00:43:45,119
necessarily spewing out matter i don't

1091
00:43:51,109 --> 00:43:47,599
know if jaclyn or dan you guys want to

1092
00:43:57,829 --> 00:43:54,630
jacqueline so

1093
00:44:01,109 --> 00:43:57,839
um so again great question

1094
00:44:04,309 --> 00:44:01,119
uh dark energy is

1095
00:44:06,390 --> 00:44:04,319
is is something that's inferred

1096
00:44:08,069 --> 00:44:06,400
right you we see a whole bunch of

1097
00:44:11,270 --> 00:44:08,079
phenomena in the universe

1098
00:44:14,630 --> 00:44:11,280
starting with supernova acceleration

1099
00:44:18,790 --> 00:44:14,640
um and and you know on from there

1100
00:44:21,190 --> 00:44:18,800
and what it actually is we're not sure

1101
00:44:22,630 --> 00:44:21,200
so certainly white holes or something

1102
00:44:25,829 --> 00:44:22,640
like that's a possibility

1103
00:44:27,750 --> 00:44:25,839
um uh some of my other colleagues and at

1104
00:44:28,470 --> 00:44:27,760
jpl will probably have more to say about

1105
00:44:30,390 --> 00:44:28,480
that

1106
00:44:32,230 --> 00:44:30,400
people are also looking for deviations

1107
00:44:35,030 --> 00:44:32,240
from general relativity

1108
00:44:36,150 --> 00:44:35,040
uh areas where einstein might have been

1109
00:44:39,510 --> 00:44:36,160
wrong

1110
00:44:42,630 --> 00:44:39,520
in order to explain dark energy

1111
00:44:43,750 --> 00:44:42,640
so the the best way we can tell the the

1112
00:44:46,550 --> 00:44:43,760
tool that we have

1113
00:44:47,750 --> 00:44:46,560

is is kind of the the cosmic web stuff

1114
00:44:52,069 --> 00:44:47,760
that i showed before it's

1115
00:44:54,390 --> 00:44:52,079
looking at the positions of galaxies

1116
00:44:56,150 --> 00:44:54,400
how clumpy they are how that clumpiness

1117
00:44:59,670 --> 00:44:56,160
changes with time

1118
00:45:02,069 --> 00:44:59,680
and this tool we can we can

1119
00:45:02,950 --> 00:45:02,079
uh this is a tool that we can have to

1120
00:45:05,589 --> 00:45:02,960
try to infer

1121
00:45:06,150 --> 00:45:05,599
how the universe is changing with time

1122
00:45:08,790 --> 00:45:06,160
um

1123
00:45:09,510 --> 00:45:08,800
how dark energy is driving the expansion

1124
00:45:11,829 --> 00:45:09,520
and then

1125
00:45:12,630 --> 00:45:11,839
from that try to eliminate classes of

1126
00:45:16,390 --> 00:45:12,640
models

1127
00:45:20,069 --> 00:45:19,510
all right thank you um let's see kai on

1128
00:45:22,470 --> 00:45:20,079
youtube

1129
00:45:23,670 --> 00:45:22,480
asks will the universe have a limit to

1130
00:45:25,829 --> 00:45:23,680
where it expands

1131
00:45:27,109 --> 00:45:25,839
and if it does will there be a great

1132
00:45:31,829 --> 00:45:27,119
compression

1133
00:45:34,150 --> 00:45:31,839
dan do you want to take that one on sure

1134
00:45:36,470 --> 00:45:34,160
it's a little scary that this is on even

1135
00:45:38,790 --> 00:45:36,480
much longer time scales than the

1136
00:45:39,750 --> 00:45:38,800
collision i talked about but it seems

1137
00:45:41,349 --> 00:45:39,760
like the universe

1138
00:45:44,390 --> 00:45:41,359

or actually the universe we know right

1139
00:45:46,230 --> 00:45:44,400
now that expansion is accelerating

1140
00:45:47,990 --> 00:45:46,240
so the universe is getting bigger and

1141
00:45:49,910 --> 00:45:48,000
bigger and that's just expected to

1142
00:45:53,270 --> 00:45:49,920
continue and continue

1143
00:45:54,150 --> 00:45:53,280
and so as it expands you know you'll

1144
00:45:56,069 --> 00:45:54,160
stop

1145
00:45:58,710 --> 00:45:56,079
being able to see distant galaxies

1146
00:46:01,670 --> 00:45:58,720
because they'll be beyond your horizon

1147
00:46:03,270 --> 00:46:01,680
um as it expands it cools and so we're

1148
00:46:06,150 --> 00:46:03,280
not looking towards a

1149
00:46:07,349 --> 00:46:06,160
crunch we don't you know 20 years ago we

1150
00:46:09,109 --> 00:46:07,359
thought maybe

1151
00:46:11,589 --> 00:46:09,119
it would expand and then collapse back

1152
00:46:13,510 --> 00:46:11,599
down at this point the current theory is

1153
00:46:15,510 --> 00:46:13,520
just expanding and expanding and

1154
00:46:18,390 --> 00:46:15,520
accelerating the expansion

1155
00:46:18,870 --> 00:46:18,400
and so it's this cosmic cooldown there's

1156
00:46:34,390 --> 00:46:18,880
a

1157
00:46:39,910 --> 00:46:34,400
from now where it

1158
00:46:43,589 --> 00:46:42,069
all right so we have one more question

1159
00:46:47,030 --> 00:46:43,599
from amaya on

1160
00:46:48,950 --> 00:46:47,040
youtube and she's asking how do you guys

1161
00:46:49,910 --> 00:46:48,960
sleep at night knowing that all these

1162
00:46:54,069 --> 00:46:49,920
scary things

1163
00:46:58,950 --> 00:46:56,630

uh to which i would answer were

1164
00:47:00,550 --> 00:46:58,960
astronomers and astrophysicists we chose

1165
00:47:02,230 --> 00:47:00,560
our line of work so that we wouldn't

1166
00:47:05,030 --> 00:47:02,240
have to sleep at night

1167
00:47:07,270 --> 00:47:05,040
so so there's your answer at least for

1168
00:47:12,630 --> 00:47:09,910
ditto i'm using the of saturday and

1169
00:47:15,910 --> 00:47:14,230
i sleep well at night because it means

1170
00:47:17,829 --> 00:47:15,920
we still have stuff out there to go and

1171
00:47:19,430 --> 00:47:17,839
discover and learn

1172
00:47:22,549 --> 00:47:19,440
if we knew everything what would we be

1173
00:47:26,150 --> 00:47:25,430
good good i'm sure those are such great

1174
00:47:29,829 --> 00:47:26,160
answers

1175
00:47:30,390 --> 00:47:29,839
um something that i do appreciate and i

1176
00:47:31,910 --> 00:47:30,400
and i

1177
00:47:33,510 --> 00:47:31,920
love about all of you is not only your

1178
00:47:35,109 --> 00:47:33,520
passion that you bring to these and the

1179
00:47:38,150 --> 00:47:35,119
joy that you bring to

1180
00:47:41,910 --> 00:47:38,160
what could be uh pretty downer topics

1181
00:47:43,190 --> 00:47:41,920
um but also your

1182
00:47:45,430 --> 00:47:43,200
and i think this is a good lesson for

1183
00:47:45,990 --> 00:47:45,440
any students out there your willingness

1184
00:47:48,069 --> 00:47:46,000
to say

1185
00:47:49,589 --> 00:47:48,079
we don't know we're we're pretty smart

1186
00:47:51,670 --> 00:47:49,599
and we know a lot of this stuff

1187
00:47:53,670 --> 00:47:51,680
and there's still things that we don't

1188
00:47:54,150 --> 00:47:53,680

know and that's what keeps you going at

1189
00:47:58,710 --> 00:47:54,160
night

1190
00:48:03,109 --> 00:48:01,030
we do have time for one last question

1191
00:48:04,870 --> 00:48:03,119
one last question

1192
00:48:06,230 --> 00:48:04,880
so it's leah what's this what's his last

1193
00:48:09,589 --> 00:48:06,240
question

1194
00:48:12,710 --> 00:48:09,599
all right yeah so uh mk3

1195
00:48:13,670 --> 00:48:12,720
gtx on youtube asks again this really

1196
00:48:15,750 --> 00:48:13,680
great question

1197
00:48:16,950 --> 00:48:15,760
what are your favorite instances of

1198
00:48:25,190 --> 00:48:16,960
science fiction

1199
00:48:29,750 --> 00:48:27,589
you've stumped everybody well i think

1200
00:48:31,670 --> 00:48:29,760
brian you're on the hook for also

1201
00:48:35,190 --> 00:48:31,680
answering

1202
00:48:41,109 --> 00:48:35,200
yeah i think brian should answer too so

1203
00:48:46,870 --> 00:48:44,309
can you repeat the question for me yeah

1204
00:48:49,750 --> 00:48:46,880
sure so uh what are your favorite

1205
00:48:55,829 --> 00:48:49,760
instances of science fiction that turned

1206
00:49:00,470 --> 00:48:59,510
oh i think if no one has an answer i

1207
00:49:09,829 --> 00:49:00,480
think i might have

1208
00:49:13,750 --> 00:49:12,630
all right um so we actually have a

1209
00:49:17,109 --> 00:49:13,760
poster about this

1210
00:49:19,589 --> 00:49:17,119
um and it's a planet called kepler-16b

1211
00:49:20,230 --> 00:49:19,599
um and we've nicknamed it tatooine

1212
00:49:23,750 --> 00:49:20,240
because

1213
00:49:27,270 --> 00:49:23,760

um it is a planet with two stars

1214
00:49:27,280 --> 00:49:34,470
i took my answer

1215
00:49:38,630 --> 00:49:37,109
i have like an extra nerdy one um i

1216
00:49:41,829 --> 00:49:38,640
remember as a kid watching

1217
00:49:44,790 --> 00:49:41,839
star trek uh the the original series

1218
00:49:45,430 --> 00:49:44,800
and it's before cell phones were super

1219
00:49:47,990 --> 00:49:45,440
uh

1220
00:49:50,150 --> 00:49:48,000
super common everywhere and also seeing

1221
00:49:52,549 --> 00:49:50,160
the tricorders that say you know dr

1222
00:49:55,750 --> 00:49:52,559
mccoy would use to to scan everybody

1223
00:49:59,750 --> 00:49:55,760
i thought wow what incredible technology

1224
00:50:03,589 --> 00:49:59,760
and here we are not so many years later

1225
00:50:05,910 --> 00:50:03,599
and your phone basically is a tricorder

1226
00:50:06,950 --> 00:50:05,920
it's a portable long-range communication

1227
00:50:09,589 --> 00:50:06,960
device

1228
00:50:11,349 --> 00:50:09,599
um and i think that having cell phones

1229
00:50:13,510 --> 00:50:11,359
around is uh

1230
00:50:15,829 --> 00:50:13,520
it's a pretty wild uh science fiction

1231
00:50:18,870 --> 00:50:15,839
dream come true

1232
00:50:22,470 --> 00:50:20,950
i have another one from star trek but on

1233
00:50:23,990 --> 00:50:22,480
the opposite side

1234
00:50:26,150 --> 00:50:24,000
i have another one from star trek on the

1235
00:50:29,270 --> 00:50:26,160
opposite side where they uh

1236
00:50:30,710 --> 00:50:29,280
they were it was not the first uh series

1237
00:50:32,790 --> 00:50:30,720
was a later one but they were

1238
00:50:35,270 --> 00:50:32,800

flying through the galaxy and they ran

1239
00:50:36,950 --> 00:50:35,280
into a cosmic string

1240
00:50:38,950 --> 00:50:36,960
and um that's something that people have

1241
00:50:41,829 --> 00:50:38,960
worked on for a while but we now

1242
00:50:42,390 --> 00:50:41,839
don't think cosmic strings exist so it

1243
00:50:45,589 --> 00:50:42,400
was sort of

1244
00:50:47,910 --> 00:50:45,599
something that sci-fi that was around

1245
00:50:48,790 --> 00:50:47,920
theoretically for a while isn't popular

1246
00:50:52,069 --> 00:50:48,800
now

1247
00:50:53,990 --> 00:50:52,079
back into popularity and

1248
00:50:55,670 --> 00:50:54,000
that will be like tattooing where they

1249
00:50:59,670 --> 00:50:55,680
they saw it ahead of time

1250
00:51:04,549 --> 00:51:02,710
tiffany i don't know there's so

1251
00:51:05,750 --> 00:51:04,559
so much interesting science fiction out

1252
00:51:08,309 --> 00:51:05,760
there about planets

1253
00:51:09,670 --> 00:51:08,319
um you know just the array of exoplanets

1254
00:51:11,910 --> 00:51:09,680
that we've discovered you know hot

1255
00:51:13,750 --> 00:51:11,920
jupiters for example were never

1256
00:51:15,910 --> 00:51:13,760
theorized before they were discovered

1257
00:51:17,589 --> 00:51:15,920
you know how does a jupiter-sized planet

1258
00:51:20,390 --> 00:51:17,599
survive so close to

1259
00:51:20,870 --> 00:51:20,400
a sun-like star that was not something

1260
00:51:22,309 --> 00:51:20,880
that

1261
00:51:24,470 --> 00:51:22,319
people ever thought about until they

1262
00:51:27,349 --> 00:51:24,480
found the first hot jupiters and so

1263
00:51:28,710 --> 00:51:27,359

you know um any scary planets that you

1264
00:51:30,630 --> 00:51:28,720
might have seen in your favorite

1265
00:51:32,710 --> 00:51:30,640
sci-fiction movie there probably

1266
00:51:34,230 --> 00:51:32,720
actually exists a planet like that out

1267
00:51:37,109 --> 00:51:34,240
there and that to me is a pretty

1268
00:51:39,109 --> 00:51:37,119
incredible thing

1269
00:51:40,630 --> 00:51:39,119
and if you if you all are gonna make me

1270
00:51:41,510 --> 00:51:40,640
answer i think what we're doing right

1271
00:51:44,790 --> 00:51:41,520
now

1272
00:51:46,950 --> 00:51:44,800
is actually my favorite thing

1273
00:51:48,230 --> 00:51:46,960
the fact that we can have your three

1274
00:51:50,790 --> 00:51:48,240
brilliant minds here

1275
00:51:52,309 --> 00:51:50,800
talking to on screen it's not a

1276
00:51:54,710 --> 00:51:52,319
telephone that we can have

1277
00:51:55,990 --> 00:51:54,720
this conversation with so many people

1278
00:51:57,670 --> 00:51:56,000
all over the world right now i think

1279
00:52:00,069 --> 00:51:57,680
that's that's pretty amazing and yeah

1280
00:52:01,510 --> 00:52:00,079
maybe a little jetsons but who thought

1281
00:52:03,430 --> 00:52:01,520
we thought we'd be here right now but

1282
00:52:05,190 --> 00:52:03,440
i'm still waiting for my flying car

1283
00:52:06,870 --> 00:52:05,200
and that is all the time that we have

1284
00:52:09,430 --> 00:52:06,880
for tonight

1285
00:52:10,710 --> 00:52:09,440
i really want to thank our speakers dr

1286
00:52:12,630 --> 00:52:10,720
tiffany kataria

1287
00:52:14,390 --> 00:52:12,640
dr jacqueline mccleary and dr daniel

1288
00:52:15,349 --> 00:52:14,400

stern for their expertise and their

1289
00:52:17,349 --> 00:52:15,359
energy

1290
00:52:19,589 --> 00:52:17,359
and next month we'll be discussing how

1291
00:52:22,630 --> 00:52:19,599
failure helps us succeed

1292
00:52:24,950 --> 00:52:22,640
the agony and inspiration of defeat

1293
00:52:27,589 --> 00:52:24,960
and as our speakers put on their their

1294
00:52:29,030 --> 00:52:27,599
alien and rocket man sunglasses

1295
00:52:30,630 --> 00:52:29,040
i'd like to thank philia and everyone

1296
00:52:31,670 --> 00:52:30,640
behind the scenes that make these talks

1297
00:52:33,589 --> 00:52:31,680
possible

1298
00:52:35,750 --> 00:52:33,599
and a big thank you to all of you who

1299
00:52:37,670 --> 00:52:35,760
join us every single month

1300
00:52:39,990 --> 00:52:37,680
remember the galaxy of horrors posters

1301
00:52:41,990 --> 00:52:40,000
are available to download for free

1302
00:52:43,670 --> 00:52:42,000
through our website and you can find the

1303
00:52:45,589 --> 00:52:43,680
link in the description

1304
00:52:47,510 --> 00:52:45,599
the exoplanet posters are up there now

1305
00:52:48,069 --> 00:52:47,520
but keep an eye out for the astrophysics

1306
00:52:49,670 --> 00:52:48,079
batch

1307
00:52:51,190 --> 00:52:49,680
that is going to be coming out as

1308
00:52:52,950 --> 00:52:51,200
halloween approaches

1309
00:52:54,630 --> 00:52:52,960
and as a special treat this halloween

1310
00:52:56,390 --> 00:52:54,640
season as promised

1311
00:52:58,630 --> 00:52:56,400
we're going to end our show with our

1312
00:53:01,670 --> 00:52:58,640
galaxy of horror videos

1313
00:53:08,470 --> 00:53:01,680

stay safe stay kind and we'll see you

1314
00:53:14,630 --> 00:53:11,589
the night sky full of stars

1315
00:53:17,510 --> 00:53:14,640
for eons human beings have gazed up

1316
00:53:19,190 --> 00:53:17,520
at its tranquil beauty taking solace in

1317
00:53:21,670 --> 00:53:19,200
the peaceful stillness

1318
00:53:22,950 --> 00:53:21,680
of this vast and eternal cosmic

1319
00:53:26,630 --> 00:53:22,960
cornucopia

1320
00:53:27,670 --> 00:53:26,640
and yet all the while lurking beyond our

1321
00:53:30,190 --> 00:53:27,680
solar system

1322
00:53:32,470 --> 00:53:30,200
among the billions of stars and the

1323
00:53:34,710 --> 00:53:32,480
exoplanets that orbit them

1324
00:53:35,670 --> 00:53:34,720
is another sort of milky way all

1325
00:53:39,270 --> 00:53:35,680
together

1326
00:53:42,069 --> 00:53:39,280
a far more sinister space a place

1327
00:53:44,549 --> 00:53:42,079
only sophisticated space telescopes and

1328
00:53:47,829 --> 00:53:44,559
imaging processes can reveal

1329
00:53:49,270 --> 00:53:47,839
a place of unequal terrors come with us

1330
00:53:51,890 --> 00:53:49,280
now if you dare

1331
00:53:55,349 --> 00:53:54,070
[Music]

1332
00:53:57,829 --> 00:53:55,359
[Applause]

1333
00:53:59,109 --> 00:53:57,839
feel discover reigns of terror the

1334
00:54:02,630 --> 00:53:59,119
killer you never see

1335
00:54:03,430 --> 00:54:02,640
coming with winds of up to 5400 miles

1336
00:54:09,349 --> 00:54:03,440
per hour

1337
00:54:12,630 --> 00:54:11,670
and don't sideways its cobalt blue color

1338
00:54:15,910 --> 00:54:12,640

fool you

1339
00:54:17,190 --> 00:54:15,920
this hazy atmosphere is riddled with

1340
00:54:20,150 --> 00:54:17,200
silicon particles

1341
00:54:22,630 --> 00:54:20,160
making this an unearthly death trap no

1342
00:54:25,750 --> 00:54:22,640
mortar would dare want to face

1343
00:54:28,069 --> 00:54:25,760
or discover the zombie worlds that exist

1344
00:54:28,950 --> 00:54:28,079
in this most inhospitable corner of the

1345
00:54:31,829 --> 00:54:28,960
galaxy

1346
00:54:32,470 --> 00:54:31,839
the poltergeist planet one of three dead

1347
00:54:34,710 --> 00:54:32,480
planets

1348
00:54:36,710 --> 00:54:34,720
shambling through the twisted magnetic

1349
00:54:39,750 --> 00:54:36,720
fields of their corpse star

1350
00:54:42,150 --> 00:54:39,760
lich which is itself the collapsed core

1351
00:54:45,190 --> 00:54:42,160
of an exploded star

1352
00:54:47,589 --> 00:54:45,200
but despite its demise this undead star

1353
00:54:49,589 --> 00:54:47,599
spins twin beams of radiation

1354
00:54:51,990 --> 00:54:49,599
that could incinerate a spaceship

1355
00:54:54,309 --> 00:54:52,000
foolish enough to venture too close

1356
00:54:56,309 --> 00:54:54,319
even if you could make it to the surface

1357
00:54:58,710 --> 00:54:56,319
your nightmares would continue

1358
00:55:00,950 --> 00:54:58,720
as the radiation from the zombie star

1359
00:55:03,270 --> 00:55:00,960
rains down on planet poltergeist

1360
00:55:04,309 --> 00:55:03,280
as well as her neighboring dead worlds

1361
00:55:08,309 --> 00:55:04,319
of dragon

1362
00:55:11,750 --> 00:55:08,319
and creating sickly irradiated auroras

1363
00:55:13,510 --> 00:55:11,760

to light up your certain death

1364
00:55:15,829 --> 00:55:13,520
these are just a sampling of the

1365
00:55:21,710 --> 00:55:15,839
terrible unwelcoming worlds

1366
00:55:25,420 --> 00:55:21,720
that inhabit power galaxy