1
00:00:00,000 --> 00:00:46,150
[Music]

2
00:00:46,160 --> 00:00:49,640
foreign

3
00:03:24,470 --> 00:01:04,469
[Music]

4
00:03:24,480 --> 00:03:28,540
so

5
00:04:04,660 --> 00:04:03,110
[Music]

6
00:04:10,630 --> 00:04:04,670
[Applause]

7
00:04:14,710 --> 00:04:12,710
hi everybody and a very pleasant good

8
00:04:16,629 --> 00:04:14,720
morning to you wherever you may be my

9
00:04:19,349 --> 00:04:16,639
name is brian white from jpl's office of

10
00:04:20,469 --> 00:04:19,359
communication and education and welcome

11
00:04:22,550 --> 00:04:20,479
to this

12
00:04:24,230 --> 00:04:22,560
celebration of the cold adam laboratory

13
00:04:25,590 --> 00:04:24,240

a unique mission illuminating our

14
00:04:26,870 --> 00:04:25,600
quantum world

15
00:04:28,390 --> 00:04:26,880
we have a wonderful panel of speakers

16
00:04:30,469 --> 00:04:28,400
for you today but we want to remind

17
00:04:32,230 --> 00:04:30,479
everyone watching at home that this is

18
00:04:33,350 --> 00:04:32,240
your space program and we want you to be

19
00:04:35,270 --> 00:04:33,360
involved

20
00:04:37,270 --> 00:04:35,280
we will have a q a at the end of this

21
00:04:38,629 --> 00:04:37,280
panel so please ask questions in the

22
00:04:40,790 --> 00:04:38,639
chat now if you don't find your chat

23
00:04:43,590 --> 00:04:40,800
right now go ahead and refresh your page

24
00:04:45,990 --> 00:04:43,600
and it will be there

25
00:04:47,909 --> 00:04:46,000
to begin it is my pleasure to introduce

26
00:04:50,070 --> 00:04:47,919
a distinguished geochemist and space

27
00:04:52,150 --> 00:04:50,080
scientist please welcome the director of

28
00:05:00,950 --> 00:04:52,160
the jet propulsion laboratory dr glory

29
00:05:05,029 --> 00:05:02,950
hello everyone hi to everyone here in

30
00:05:07,590 --> 00:05:05,039
the room and everybody watching online

31
00:05:10,310 --> 00:05:07,600
welcome to this great celebration of

32
00:05:12,870 --> 00:05:10,320
four years of the cold atom lab up on

33
00:05:17,270 --> 00:05:12,880
iss let's give them a hand four years

34
00:05:21,350 --> 00:05:18,710
i'm so happy to be here you know here at

35
00:05:24,070 --> 00:05:21,360
jpl we are all about driving the

36
00:05:25,029 --> 00:05:24,080
frontiers of scientific discovery from

37
00:05:26,950 --> 00:05:25,039
space

38
00:05:28,230 --> 00:05:26,960

you probably know us as the cool mars

39
00:05:30,070 --> 00:05:28,240
rover people

40
00:05:31,909 --> 00:05:30,080
and we are

41
00:05:34,710 --> 00:05:31,919
also celebrating this year 10 years of

42
00:05:37,189 --> 00:05:34,720
mars curiosity rover on mars so uh

43
00:05:39,430 --> 00:05:37,199
celebrating lots of anniversaries but we

44
00:05:41,430 --> 00:05:39,440
do more than mars rovers we do

45
00:05:44,070 --> 00:05:41,440
astrophysics missions we study our home

46
00:05:45,749 --> 00:05:44,080
planet of earth and this is a great

47
00:05:48,469 --> 00:05:45,759
example of driving the frontiers of

48
00:05:50,469 --> 00:05:48,479
science from space fundamental physics

49
00:05:53,510 --> 00:05:50,479
basic knowledge about

50
00:05:56,070 --> 00:05:53,520
the behavior of matter and energy and

51
00:05:57,670 --> 00:05:56,080
gravity really understanding the truth

52
00:05:59,510 --> 00:05:57,680
and when they say fundamental physics it

53
00:06:01,830 --> 00:05:59,520
doesn't get more fundamental than the

54
00:06:03,909 --> 00:06:01,840
kind of work that we're doing with this

55
00:06:05,430 --> 00:06:03,919
cutting edge laboratory flying on the

56
00:06:08,070 --> 00:06:05,440
space station that

57
00:06:10,790 --> 00:06:08,080
zero g environment gives us a whole new

58
00:06:12,629 --> 00:06:10,800
way of exploring fundamental physics

59
00:06:14,790 --> 00:06:12,639
you're going to hear tons more about

60
00:06:17,189 --> 00:06:14,800
that from people who are highly

61
00:06:19,189 --> 00:06:17,199
qualified to talk about it both the

62
00:06:21,350 --> 00:06:19,199
scientists that are involved in it and

63
00:06:23,189 --> 00:06:21,360

i'm thrilled that we have eric cornell a

64
00:06:25,189 --> 00:06:23,199
nobel prize winner here one of the real

65
00:06:27,510 --> 00:06:25,199
founders of this field

66
00:06:30,230 --> 00:06:27,520
with us today we've got christine

67
00:06:32,230 --> 00:06:30,240
who's who has uh helped us with

68
00:06:34,629 --> 00:06:32,240
installing the update to the cold adam

69
00:06:36,950 --> 00:06:34,639
lab a great astronaut from the iss

70
00:06:38,629 --> 00:06:36,960
christina really great to have you here

71
00:06:40,870 --> 00:06:38,639
as well as our whole

72
00:06:42,390 --> 00:06:40,880
jpl team and science team from around

73
00:06:43,270 --> 00:06:42,400
the country and hopefully around the

74
00:06:45,830 --> 00:06:43,280
world

75
00:06:48,150 --> 00:06:45,840
everyone who has helped us

76
00:06:50,710 --> 00:06:48,160
get to this point we also craig kundra

77
00:06:52,309 --> 00:06:50,720
from nasa headquarters here who runs the

78
00:06:55,029 --> 00:06:52,319
who oversees the whole biological and

79
00:06:57,990 --> 00:06:55,039
physical research program for nasa so

80
00:07:00,309 --> 00:06:58,000
we've got a cast of superstars here to

81
00:07:02,550 --> 00:07:00,319
talk with you about the extraordinary

82
00:07:05,510 --> 00:07:02,560
achievements of the cold adam lab

83
00:07:07,430 --> 00:07:05,520
on iss and i think the best is yet to

84
00:07:09,749 --> 00:07:07,440
come we're really just

85
00:07:12,230 --> 00:07:09,759
dipping our toe into this uncharted

86
00:07:14,710 --> 00:07:12,240
water of fundamental physics from space

87
00:07:16,870 --> 00:07:14,720
there's so much more to do and so as we

88
00:07:18,710 --> 00:07:16,880

celebrate where where we've gotten to in

89
00:07:21,430 --> 00:07:18,720
this last four years i really hope today

90
00:07:23,430 --> 00:07:21,440
will also talk about where we're headed

91
00:07:25,909 --> 00:07:23,440
what's next what is the next frontier of

92
00:07:27,670 --> 00:07:25,919
discovery as we continue to update

93
00:07:29,510 --> 00:07:27,680
the cold atom lab

94
00:07:31,029 --> 00:07:29,520
on the space station and

95
00:07:32,870 --> 00:07:31,039
you know the amazing one of the other

96
00:07:35,510 --> 00:07:32,880
amazing things about this experiment is

97
00:07:36,950 --> 00:07:35,520
it's a great example of nasa's human

98
00:07:39,589 --> 00:07:36,960
space flight program working together

99
00:07:42,070 --> 00:07:39,599
with a science program to really advance

100
00:07:44,309 --> 00:07:42,080
the frontiers we could not do this work

101
00:07:47,110 --> 00:07:44,319
without amazing astronauts on the iss to

102
00:07:48,710 --> 00:07:47,120
help us run these experiments it's um

103
00:07:50,150 --> 00:07:48,720
you know those of us who are lab rats

104
00:07:51,670 --> 00:07:50,160
like me you know we're in there sort of

105
00:07:53,909 --> 00:07:51,680
tweaking things all the time and when

106
00:07:56,469 --> 00:07:53,919
you're labs in space that's impossible

107
00:07:58,309 --> 00:07:56,479
to do without the assistance of our

108
00:08:00,390 --> 00:07:58,319
highly trained and very collaborative

109
00:08:02,230 --> 00:08:00,400
astronaut corps who support everything

110
00:08:04,070 --> 00:08:02,240
we're trying to do with science so we're

111
00:08:05,670 --> 00:08:04,080
so grateful for that collaboration we're

112
00:08:07,670 --> 00:08:05,680
grateful for the collaboration with

113
00:08:09,430 --> 00:08:07,680

headquarters with international partners

114
00:08:11,749 --> 00:08:09,440
we're working on the next phase of cold

115
00:08:14,629 --> 00:08:11,759
adam lab with our partners in germany

116
00:08:18,309 --> 00:08:14,639
and uh the best is really yet to come so

117
00:08:20,629 --> 00:08:18,319
i i wish you a fabulous celebration of

118
00:08:22,070 --> 00:08:20,639
some truly mind-blowing science that

119
00:08:24,309 --> 00:08:22,080
you're going to hear about

120
00:08:25,510 --> 00:08:24,319
i mean well honestly so i've been up

121
00:08:27,029 --> 00:08:25,520
talking a lot in the last few weeks

122
00:08:28,710 --> 00:08:27,039
about extraordinary images from the

123
00:08:30,629 --> 00:08:28,720
james webb space telescope right those

124
00:08:31,909 --> 00:08:30,639
are pretty cool and that's an amazing

125
00:08:33,829 --> 00:08:31,919
accomplishment and i've been talking

126
00:08:36,949 --> 00:08:33,839
about how the instrument that we built

127
00:08:39,350 --> 00:08:36,959
here at jpl miri is really really cold

128
00:08:41,190 --> 00:08:39,360
it's operating at you know 6.4 kelvin

129
00:08:43,269 --> 00:08:41,200
right now and you all are like oh my god

130
00:08:46,070 --> 00:08:43,279
i'm hot i need a fan that's like way too

131
00:08:47,910 --> 00:08:46,080
hot for us right pico kelvin above

132
00:08:49,509 --> 00:08:47,920
absolute zero like this it's just

133
00:08:51,990 --> 00:08:49,519
mind-blowing the the science that's

134
00:08:53,750 --> 00:08:52,000
taking place here and um

135
00:08:56,230 --> 00:08:53,760
the only way to get the science done is

136
00:08:58,790 --> 00:08:56,240
on something like the iss with something

137
00:09:00,550 --> 00:08:58,800
like the cold adam lab so extraordinary

138
00:09:03,190 --> 00:09:00,560

accomplishments to celebrate very bright

139
00:09:04,310 --> 00:09:03,200
future ahead and we just appreciate the

140
00:09:06,230 --> 00:09:04,320
students

141
00:09:07,990 --> 00:09:06,240
all of our interns who are here the pis

142
00:09:09,430 --> 00:09:08,000
who are here the engineers who helped

143
00:09:11,509 --> 00:09:09,440
bring this to life the astronauts who've

144
00:09:14,389 --> 00:09:11,519
worked with us and partners around the

145
00:09:16,550 --> 00:09:14,399
globe in making this happen enjoy

146
00:09:19,269 --> 00:09:16,560
this nerd fest that you are about to

147
00:09:21,990 --> 00:09:19,279
have on fundamental physics from space

148
00:09:30,389 --> 00:09:22,000
and again welcome to jpl we're thrilled

149
00:09:35,430 --> 00:09:32,389
thank you director galeshen and as she

150
00:09:37,030 --> 00:09:35,440
said let your nerd flag fly today now

151
00:09:38,710 --> 00:09:37,040
our next speaker is responsible for

152
00:09:40,949 --> 00:09:38,720
providing strategic direction and

153
00:09:42,710 --> 00:09:40,959
overseeing the planning and execution of

154
00:09:44,949 --> 00:09:42,720
the two-pronged mission of pioneering

155
00:09:46,949 --> 00:09:44,959
scientific discovery and enabling human

156
00:09:48,710 --> 00:09:46,959
space flight exploration he is the

157
00:09:50,550 --> 00:09:48,720
biological and physical sciences

158
00:09:52,630 --> 00:09:50,560
division director and the science

159
00:09:59,670 --> 00:09:52,640
mission directorate at nasa headquarters

160
00:10:02,710 --> 00:10:01,030
thank you brian it's a great pleasure to

161
00:10:05,110 --> 00:10:02,720
be here to celebrate four years of the

162
00:10:06,790 --> 00:10:05,120
cold adam laboratory

163
00:10:08,069 --> 00:10:06,800

as brian just mentioned in the

164
00:10:09,590 --> 00:10:08,079
biological and physical sciences

165
00:10:11,750 --> 00:10:09,600
division we have a two-pronged mission

166
00:10:14,230 --> 00:10:11,760
of pioneering scientific discovery and

167
00:10:16,949 --> 00:10:14,240
enabling sustainable exploration

168
00:10:19,670 --> 00:10:16,959
cal is the exemplar of pioneering

169
00:10:21,110 --> 00:10:19,680
scientific discovery in bps biological

170
00:10:24,150 --> 00:10:21,120
and physical sciences

171
00:10:25,269 --> 00:10:24,160
um unlike our uh scientific brethren in

172
00:10:26,389 --> 00:10:25,279
the rest of the science mission

173
00:10:29,910 --> 00:10:26,399
directorate

174
00:10:32,790 --> 00:10:29,920
which typically study space or from or

175
00:10:34,470 --> 00:10:32,800
the earth from space at very large

176
00:10:36,790 --> 00:10:34,480
scales typically

177
00:10:38,790 --> 00:10:36,800
in bps we are experimentalists and cal

178
00:10:41,430 --> 00:10:38,800
is a great example of an experimental

179
00:10:43,590 --> 00:10:41,440
program that is capitalizing on the

180
00:10:46,470 --> 00:10:43,600
unique environment in low earth orbit on

181
00:10:49,110 --> 00:10:46,480
the iss which is basically long duration

182
00:10:51,430 --> 00:10:49,120
free fall where atoms can be studied at

183
00:10:53,509 --> 00:10:51,440
ultra cold temperatures in extremely

184
00:10:55,750 --> 00:10:53,519
weak potentials and you'll hear a lot

185
00:10:58,069 --> 00:10:55,760
more about that in the subsequent talks

186
00:11:00,630 --> 00:10:58,079
but at a top level cal has already had

187
00:11:01,910 --> 00:11:00,640
many firsts

188
00:11:05,110 --> 00:11:01,920

recently

189
00:11:07,110 --> 00:11:05,120
the cal project published on quantum

190
00:11:10,630 --> 00:11:07,120
bubbles you'll hear a bit more about

191
00:11:13,829 --> 00:11:10,640
this later and just last week at the iss

192
00:11:15,910 --> 00:11:13,839
research and development conference

193
00:11:18,150 --> 00:11:15,920
nathan lunblatt representing the bubble

194
00:11:20,630 --> 00:11:18,160
team and the jpl ops team accepted an

195
00:11:23,110 --> 00:11:20,640
award for the physical science uh result

196
00:11:24,630 --> 00:11:23,120
of the year award at that conference

197
00:11:26,389 --> 00:11:24,640
very noteworthy

198
00:11:28,790 --> 00:11:26,399
cal has created the first boze einstein

199
00:11:31,590 --> 00:11:28,800
condensates in space

200
00:11:32,710 --> 00:11:31,600
and has created the coldest place in

201
00:11:35,190 --> 00:11:32,720
space

202
00:11:37,590 --> 00:11:35,200
and so cal as you'll hear more about

203
00:11:41,110 --> 00:11:37,600
later has pioneered in many respects

204
00:11:42,949 --> 00:11:41,120
but with pioneering very often it comes

205
00:11:45,590 --> 00:11:42,959
difficulty and i want to give a shout

206
00:11:47,190 --> 00:11:45,600
out to the broad number of people that

207
00:11:50,310 --> 00:11:47,200
have been involved in making callus

208
00:11:53,110 --> 00:11:50,320
success starting with here at jpl the

209
00:11:54,949 --> 00:11:53,120
hardware developers and operations team

210
00:11:56,710 --> 00:11:54,959
the science team

211
00:11:58,790 --> 00:11:56,720
the principal investigators and their

212
00:12:01,110 --> 00:11:58,800
teams coming together to solve

213
00:12:03,430 --> 00:12:01,120

many challenges in operating cal

214
00:12:05,670 --> 00:12:03,440
the iss program in

215
00:12:07,269 --> 00:12:05,680
in supporting operations

216
00:12:11,670 --> 00:12:07,279
and

217
00:12:13,590 --> 00:12:11,680
course as you'll hear later

218
00:12:15,430 --> 00:12:13,600
are astronauts and one in particular

219
00:12:16,230 --> 00:12:15,440
you'll hear from today

220
00:12:18,069 --> 00:12:16,240
so

221
00:12:21,269 --> 00:12:18,079
pioneering isn't easy and this group has

222
00:12:22,790 --> 00:12:21,279
done a fantastic job to be tenacious

223
00:12:24,870 --> 00:12:22,800
patient

224
00:12:27,030 --> 00:12:24,880
and show that fortitude to to bring all

225
00:12:28,150 --> 00:12:27,040
these results having said that we know

226
00:12:29,910 --> 00:12:28,160
that there's some really exciting

227
00:12:31,030 --> 00:12:29,920
results uh in future because just

228
00:12:34,069 --> 00:12:31,040
recently

229
00:12:36,069 --> 00:12:34,079
uh cal has demonstrated dual species

230
00:12:38,150 --> 00:12:36,079
bose einstein condensates uh you learn

231
00:12:40,150 --> 00:12:38,160
about that and demonstrated atom

232
00:12:41,430 --> 00:12:40,160
interferometry so you'll hear about

233
00:12:42,550 --> 00:12:41,440
these things which are opening up a

234
00:12:44,870 --> 00:12:42,560
whole new

235
00:12:45,670 --> 00:12:44,880
lane of research for the coming years

236
00:12:47,670 --> 00:12:45,680
and

237
00:12:49,990 --> 00:12:47,680
with that i'd like to again

238
00:12:51,430 --> 00:12:50,000

emphasize my thanks to the broad cal

239
00:12:52,550 --> 00:12:51,440
team uh

240
00:12:54,629 --> 00:12:52,560
on their

241
00:12:55,829 --> 00:12:54,639
perseverance and dedication and to the

242
00:13:01,670 --> 00:12:55,839
great successes that we're able to

243
00:13:13,430 --> 00:13:05,150
and now let's hear more from john kalas

244
00:13:17,350 --> 00:13:15,590
good morning as mentioned i'm john kalas

245
00:13:19,670 --> 00:13:17,360
i'm the program manager for fundamental

246
00:13:21,190 --> 00:13:19,680
physics here at jpl

247
00:13:23,750 --> 00:13:21,200
let me also

248
00:13:25,590 --> 00:13:23,760
add my welcome to the cal science team

249
00:13:27,990 --> 00:13:25,600
and to all our distinguished guests here

250
00:13:30,710 --> 00:13:28,000
today and also let me

251
00:13:33,990 --> 00:13:30,720
also acknowledge the great technological

252
00:13:35,670 --> 00:13:34,000
and scientific accomplishment of the cal

253
00:13:37,829 --> 00:13:35,680
experiment

254
00:13:40,949 --> 00:13:37,839
so i'd like to give a little um

255
00:13:42,550 --> 00:13:40,959
scientific context to today's

256
00:13:45,030 --> 00:13:42,560
celebration

257
00:13:47,590 --> 00:13:45,040
so let me start here this is one of the

258
00:13:50,069 --> 00:13:47,600
recently released images from the james

259
00:13:51,189 --> 00:13:50,079
webb space telescope this is their

260
00:13:54,310 --> 00:13:51,199
first

261
00:13:56,470 --> 00:13:54,320
deep field survey and what you can see

262
00:14:00,870 --> 00:13:56,480
in this image which is no more than a

263
00:14:02,389 --> 00:14:00,880

grain of sand held at arm's length are

264
00:14:07,350 --> 00:14:02,399
thousands of galaxies

265
00:14:09,350 --> 00:14:07,360
a few stars and the effects of gravity

266
00:14:11,269 --> 00:14:09,360
these galaxies

267
00:14:13,750 --> 00:14:11,279
if they are like our own milky way

268
00:14:16,389 --> 00:14:13,760
galaxy consists of

269
00:14:18,550 --> 00:14:16,399
hundreds of billions of stars

270
00:14:22,389 --> 00:14:18,560
and so by extrapolation of that grain of

271
00:14:24,230 --> 00:14:22,399
sand to the entirety of the sky

272
00:14:27,910 --> 00:14:24,240
we can estimate that there's something

273
00:14:30,230 --> 00:14:27,920
of the order of 10 to the 22

274
00:14:32,389 --> 00:14:30,240
stellar systems out there in the

275
00:14:36,150 --> 00:14:32,399
observable universe this is an

276
00:14:38,470 --> 00:14:36,160
incredible domain of exploration

277
00:14:40,949 --> 00:14:38,480
and this observable universe is

278
00:14:43,430 --> 00:14:40,959
beautifully described by two great

279
00:14:45,350 --> 00:14:43,440
theories of fundamental physics the

280
00:14:48,150 --> 00:14:45,360
general theory of relativity which tells

281
00:14:49,910 --> 00:14:48,160
us about gravity and the standard model

282
00:14:52,150 --> 00:14:49,920
of particle physics which is essentially

283
00:14:53,030 --> 00:14:52,160
quantum mechanics or quantum field

284
00:14:55,269 --> 00:14:53,040
theory

285
00:14:58,629 --> 00:14:55,279
but as magnificent as these theories are

286
00:15:01,910 --> 00:14:58,639
and explaining what we see here we are

287
00:15:03,189 --> 00:15:01,920
only seeing a tiny fraction of our

288
00:15:04,790 --> 00:15:03,199

universe

289
00:15:07,590 --> 00:15:04,800
that's because

290
00:15:08,870 --> 00:15:07,600
more than 95 percent of our universe is

291
00:15:12,710 --> 00:15:08,880
dark

292
00:15:15,430 --> 00:15:12,720
that only a tiny fraction is luminous

293
00:15:18,470 --> 00:15:15,440
so this darkness is in two forms what we

294
00:15:20,790 --> 00:15:18,480
call dark energy and dark matter but we

295
00:15:23,030 --> 00:15:20,800
don't know what these are

296
00:15:24,710 --> 00:15:23,040
our standard model that i was just

297
00:15:26,470 --> 00:15:24,720
mentioning which beautifully describes

298
00:15:29,749 --> 00:15:26,480
the observable universe

299
00:15:32,710 --> 00:15:29,759
doesn't explain this this is a gaping

300
00:15:35,509 --> 00:15:32,720
hole in our understanding

301
00:15:37,110 --> 00:15:35,519
and further our very existence is

302
00:15:39,509 --> 00:15:37,120
incompatible

303
00:15:42,069 --> 00:15:39,519
with the standard model because the

304
00:15:45,030 --> 00:15:42,079
universe is made up of only what we call

305
00:15:46,550 --> 00:15:45,040
baryonic matter and no antimatter the

306
00:15:47,590 --> 00:15:46,560
standard model

307
00:15:48,949 --> 00:15:47,600
would

308
00:15:51,189 --> 00:15:48,959
explain that we should have equal

309
00:15:53,509 --> 00:15:51,199
amounts of each

310
00:15:55,189 --> 00:15:53,519
and so why is this

311
00:15:57,269 --> 00:15:55,199
and and further

312
00:15:59,829 --> 00:15:57,279
general relativity or theory of gravity

313
00:16:02,230 --> 00:15:59,839

is it really the last word on things why

314
00:16:03,829 --> 00:16:02,240
have we been unable to unify gravity

315
00:16:05,829 --> 00:16:03,839
with the other forces of nature with

316
00:16:07,910 --> 00:16:05,839
this standard model so these are

317
00:16:11,110 --> 00:16:07,920
significant shortcomings in our

318
00:16:13,509 --> 00:16:11,120
understanding of this vast universe and

319
00:16:14,550 --> 00:16:13,519
again we only observe a tiny fraction of

320
00:16:16,949 --> 00:16:14,560
it

321
00:16:18,710 --> 00:16:16,959
so our our great

322
00:16:21,030 --> 00:16:18,720
uh scientific

323
00:16:22,870 --> 00:16:21,040
vehicles exploration are giant

324
00:16:25,030 --> 00:16:22,880
accelerators on the ground our

325
00:16:28,470 --> 00:16:25,040
magnificent observatories have been

326
00:16:32,710 --> 00:16:28,480
unable to shed light on many of these

327
00:16:36,230 --> 00:16:32,720
great uh questions so how can we answer

328
00:16:38,550 --> 00:16:36,240
these questions well perhaps one way is

329
00:16:41,670 --> 00:16:38,560
to go into space

330
00:16:44,629 --> 00:16:41,680
the microgravity environment of space

331
00:16:47,110 --> 00:16:44,639
creates an opportunity for us to create

332
00:16:48,550 --> 00:16:47,120
perhaps the most precise sensors

333
00:16:51,509 --> 00:16:48,560
possible

334
00:16:54,870 --> 00:16:51,519
cold atoms free from the effects of

335
00:16:58,870 --> 00:16:54,880
gravity become these ultra precise

336
00:17:01,110 --> 00:16:58,880
quiescent tiny probes that we can use uh

337
00:17:02,230 --> 00:17:01,120
to explore these great scientific

338
00:17:04,390 --> 00:17:02,240

questions

339
00:17:06,630 --> 00:17:04,400
so okay specifically how would we go

340
00:17:08,069 --> 00:17:06,640
about investigating these questions well

341
00:17:10,710 --> 00:17:08,079
what we are trying to do in the

342
00:17:14,150 --> 00:17:10,720
fundamental physics program is use a

343
00:17:17,669 --> 00:17:14,160
suite of exploration technologies one is

344
00:17:19,590 --> 00:17:17,679
to use clocks by putting optical clocks

345
00:17:22,069 --> 00:17:19,600
in space free from the effects of

346
00:17:23,990 --> 00:17:22,079
gravity they become more precise clocks

347
00:17:25,909 --> 00:17:24,000
in space are more accurate than clocks

348
00:17:28,150 --> 00:17:25,919
here on the surface of the earth

349
00:17:31,510 --> 00:17:28,160
by having these clocks in space and

350
00:17:33,909 --> 00:17:31,520
having them operate so precisely we can

351
00:17:36,070 --> 00:17:33,919
monitor their frequency or their tick

352
00:17:38,549 --> 00:17:36,080
and look for deviations that are due to

353
00:17:42,150 --> 00:17:38,559
changes in gravity or the presence of

354
00:17:44,470 --> 00:17:42,160
tiny unseen forces

355
00:17:47,590 --> 00:17:44,480
we can also use the moon

356
00:17:50,070 --> 00:17:47,600
as a laboratory for exploration by using

357
00:17:52,549 --> 00:17:50,080
new laser ranging techniques we can make

358
00:17:55,190 --> 00:17:52,559
the moon a test mass and literally

359
00:17:57,669 --> 00:17:55,200
repeat the experiment that galileo did

360
00:17:59,669 --> 00:17:57,679
from the leaning tower of pisa and look

361
00:18:01,029 --> 00:17:59,679
and test the equivalence principle of

362
00:18:02,710 --> 00:18:01,039
gravity

363
00:18:04,150 --> 00:18:02,720

might shed light on many of these great

364
00:18:05,909 --> 00:18:04,160
questions

365
00:18:08,710 --> 00:18:05,919
we can also do

366
00:18:11,669 --> 00:18:08,720
create deep space quantum links where we

367
00:18:14,470 --> 00:18:11,679
use quantum mechanics itself

368
00:18:15,830 --> 00:18:14,480
to look for deviations and our

369
00:18:17,990 --> 00:18:15,840
understanding of these scientific

370
00:18:20,310 --> 00:18:18,000
theories perhaps revealing

371
00:18:22,310 --> 00:18:20,320
hidden variables or unseen

372
00:18:24,789 --> 00:18:22,320
new physics

373
00:18:27,590 --> 00:18:24,799
not directly to these questions but also

374
00:18:29,990 --> 00:18:27,600
equally important is we can use

375
00:18:32,870 --> 00:18:30,000
microgravity environments to explore

376
00:18:35,590 --> 00:18:32,880
dusty complex plasmas to reveal things

377
00:18:37,190 --> 00:18:35,600
about phase transitions and critical

378
00:18:40,390 --> 00:18:37,200
theories

379
00:18:43,029 --> 00:18:40,400
but we can also put atom interferometers

380
00:18:45,750 --> 00:18:43,039
in space this is where we take ultra

381
00:18:48,070 --> 00:18:45,760
cold atoms and we use their quantum

382
00:18:49,990 --> 00:18:48,080
mechanical wave nature

383
00:18:52,230 --> 00:18:50,000
to create an interferometer which

384
00:18:55,190 --> 00:18:52,240
becomes one of the most precise tools

385
00:18:56,470 --> 00:18:55,200
for measuring our physical universe

386
00:18:58,310 --> 00:18:56,480
so cal

387
00:19:01,669 --> 00:18:58,320
is one of those instruments that is

388
00:19:03,430 --> 00:19:01,679

pioneering this technique to explore the

389
00:19:06,310 --> 00:19:03,440
these great physical questions and to

390
00:19:09,350 --> 00:19:06,320
reveal potentially new physics and so

391
00:19:11,590 --> 00:19:09,360
today we are celebrating cal and i think

392
00:19:14,310 --> 00:19:11,600
this is a magnificent

393
00:19:20,220 --> 00:19:14,320
way to acknowledge our exploration into

394
00:19:20,230 --> 00:19:33,990
[Applause]

395
00:19:37,510 --> 00:19:35,350
good morning

396
00:19:41,190 --> 00:19:37,520
my name is kamal dreary and i'm the

397
00:19:43,190 --> 00:19:41,200
called adam lab project manager

398
00:19:46,630 --> 00:19:43,200
so i'm here to

399
00:19:50,310 --> 00:19:46,640
basically i will be introducing our

400
00:19:54,630 --> 00:19:52,950
astronaut christina cook

401
00:19:55,669 --> 00:19:54,640
but i would like to take a few minutes

402
00:19:58,230 --> 00:19:55,679
to

403
00:19:59,350 --> 00:19:58,240
basically also thank our

404
00:20:00,150 --> 00:19:59,360
team

405
00:20:03,669 --> 00:20:00,160
and

406
00:20:06,630 --> 00:20:04,870
cal

407
00:20:08,470 --> 00:20:06,640
so it's a little hard to do it in a

408
00:20:11,669 --> 00:20:08,480
couple of minutes but since you're going

409
00:20:12,789 --> 00:20:11,679
to hear all the details from

410
00:20:17,350 --> 00:20:12,799
both

411
00:20:25,990 --> 00:20:19,190
our nobel laureate

412
00:20:32,870 --> 00:20:29,830
i will go over the presentations if

413
00:20:34,390 --> 00:20:32,880

you don't mind okay so first uh we will

414
00:20:36,630 --> 00:20:34,400
hear from

415
00:20:38,950 --> 00:20:36,640
christina astronaut christina koch and

416
00:20:39,909 --> 00:20:38,960
she will talk about mission

417
00:20:41,990 --> 00:20:39,919
space

418
00:20:43,750 --> 00:20:42,000
station science

419
00:20:44,710 --> 00:20:43,760
followed by

420
00:20:45,750 --> 00:20:44,720
um

421
00:20:48,950 --> 00:20:45,760
jason

422
00:20:50,950 --> 00:20:48,960
williams who will talk about the

423
00:20:52,390 --> 00:20:50,960
science of cal or some of the

424
00:20:54,870 --> 00:20:52,400
accomplishments

425
00:21:00,630 --> 00:20:57,510
professor eric cornell will talk about

426
00:21:03,190 --> 00:21:00,640
quantum science in space

427
00:21:05,110 --> 00:21:03,200
so um

428
00:21:07,270 --> 00:21:05,120
we're here today

429
00:21:10,230 --> 00:21:07,280
celebrating four years of quantum

430
00:21:12,390 --> 00:21:10,240
science in space

431
00:21:14,310 --> 00:21:12,400
because of tremendous

432
00:21:16,710 --> 00:21:14,320
uh determination

433
00:21:19,750 --> 00:21:16,720
and dedication by the people

434
00:21:21,029 --> 00:21:19,760
that actually proposed

435
00:21:22,789 --> 00:21:21,039
design

436
00:21:24,149 --> 00:21:22,799
built

437
00:21:26,149 --> 00:21:24,159
and now

438
00:21:28,149 --> 00:21:26,159

operating and using

439
00:21:31,110 --> 00:21:28,159
called adam lab

440
00:21:33,510 --> 00:21:31,120
we're also here

441
00:21:35,029 --> 00:21:33,520
to celebrate cals first and there are

442
00:21:36,950 --> 00:21:35,039
many and

443
00:21:40,070 --> 00:21:36,960
so you heard some of them

444
00:21:44,310 --> 00:21:42,070
there is still so much

445
00:21:46,230 --> 00:21:44,320
that we can still do in the quantum

446
00:21:47,750 --> 00:21:46,240
world so basically

447
00:21:50,950 --> 00:21:47,760
um

448
00:21:52,230 --> 00:21:50,960
we're not done yet so we this is four

449
00:21:54,070 --> 00:21:52,240
years and

450
00:21:57,990 --> 00:21:54,080
uh in space

451
00:22:00,870 --> 00:21:58,000
and we've been extended to operate until

452
00:22:03,190 --> 00:22:00,880
at least 2026 and this is made possible

453
00:22:05,510 --> 00:22:03,200
because of all the help and the support

454
00:22:08,070 --> 00:22:05,520
we get from

455
00:22:10,310 --> 00:22:08,080
also our crew office

456
00:22:14,870 --> 00:22:10,320
so

457
00:22:19,390 --> 00:22:16,870
it was launched

458
00:22:21,029 --> 00:22:19,400
to iss on may 21st

459
00:22:22,149 --> 00:22:21,039
2018

460
00:22:24,470 --> 00:22:22,159
on

461
00:22:29,029 --> 00:22:24,480
cygnus

462
00:22:30,390 --> 00:22:29,039
from wallops in virginia nasa's wallops

463
00:22:33,909 --> 00:22:30,400

and

464
00:22:35,990 --> 00:22:33,919
we took about a few months to perform

465
00:22:39,350 --> 00:22:36,000
what we call commissioning

466
00:22:40,549 --> 00:22:39,360
and we started our science operations

467
00:22:42,149 --> 00:22:40,559
around

468
00:22:45,590 --> 00:22:42,159
this time august

469
00:22:48,390 --> 00:22:45,600
2018 so we've been operating in space

470
00:22:50,710 --> 00:22:48,400
since so in a sense if

471
00:22:51,909 --> 00:22:50,720
i want you to remember so the called

472
00:22:52,950 --> 00:22:51,919
adam lab

473
00:22:54,390 --> 00:22:52,960
is

474
00:22:55,669 --> 00:22:54,400
a laboratory

475
00:22:57,750 --> 00:22:55,679
orbiting

476
00:22:59,190 --> 00:22:57,760
earth

477
00:23:00,870 --> 00:22:59,200
operated

478
00:23:05,270 --> 00:23:00,880
remotely

479
00:23:09,029 --> 00:23:07,510
the coal atom lab

480
00:23:11,350 --> 00:23:09,039
is the size of

481
00:23:12,310 --> 00:23:11,360
like a mini refrigerator so if if you

482
00:23:15,430 --> 00:23:12,320
can see

483
00:23:18,870 --> 00:23:15,440
astronaut christina coke she's facing

484
00:23:20,070 --> 00:23:18,880
the science instrument which fits in uh

485
00:23:23,190 --> 00:23:20,080
four quarter

486
00:23:24,789 --> 00:23:23,200
one four quadrant and then we have all

487
00:23:27,510 --> 00:23:24,799
the power electronics and so on in a

488
00:23:28,630 --> 00:23:27,520

single locker

489
00:23:29,430 --> 00:23:28,640
so

490
00:23:30,549 --> 00:23:29,440
um

491
00:23:33,430 --> 00:23:30,559
in a sense

492
00:23:36,470 --> 00:23:33,440
the called atom lab is the first quantum

493
00:23:40,950 --> 00:23:36,480
science laboratory in space

494
00:23:43,590 --> 00:23:40,960
that is remotely operated from earth

495
00:23:45,909 --> 00:23:43,600
in terms of cold when we think about a

496
00:23:48,710 --> 00:23:45,919
cold place on earth we think of

497
00:23:50,950 --> 00:23:48,720
antarctica for example right

498
00:23:53,909 --> 00:23:50,960
with a temperature of

499
00:23:56,390 --> 00:23:53,919
like in a winter night of minus 83

500
00:23:59,269 --> 00:23:56,400
degree celsius

501
00:24:03,510 --> 00:23:59,279
or if we think of the moon

502
00:24:06,390 --> 00:24:03,520
the far side of the moon is about minus

503
00:24:07,669 --> 00:24:06,400
173

504
00:24:10,310 --> 00:24:07,679
but all this

505
00:24:12,310 --> 00:24:10,320
doesn't come close to the temperatures

506
00:24:14,390 --> 00:24:12,320
that we daily

507
00:24:17,269 --> 00:24:14,400
uh generate

508
00:24:19,510 --> 00:24:17,279
or achieve with the cold atom lab

509
00:24:21,590 --> 00:24:19,520
and

510
00:24:23,669 --> 00:24:21,600
even if we compare to space now i'm

511
00:24:24,630 --> 00:24:23,679
going to shift a little bit the unit so

512
00:24:28,710 --> 00:24:24,640
space

513
00:24:29,909 --> 00:24:28,720

has an average of 3 kelvin temperature

514
00:24:32,470 --> 00:24:29,919
and

515
00:24:36,390 --> 00:24:32,480
with the cold atom as you will hear in

516
00:24:38,149 --> 00:24:36,400
in a few minutes we've been able to

517
00:24:39,269 --> 00:24:38,159
achieve

518
00:24:41,510 --> 00:24:39,279
minus

519
00:24:42,630 --> 00:24:41,520
52 pico kelvins

520
00:24:44,789 --> 00:24:42,640
and

521
00:24:49,430 --> 00:24:44,799
most of our experiments

522
00:24:52,630 --> 00:24:49,440
use about 100 100 nano nano kelvins

523
00:24:53,830 --> 00:24:52,640
so there is a huge difference and that's

524
00:24:56,390 --> 00:24:53,840
why

525
00:25:00,789 --> 00:24:56,400
when you look up and look at iss it's

526
00:25:04,310 --> 00:25:00,799
basically the coldest spot in space

527
00:25:05,669 --> 00:25:04,320
so i want you to remember the 50 to 52

528
00:25:09,269 --> 00:25:05,679
pico kelvin

529
00:25:11,110 --> 00:25:09,279
um done with the cold atom lab

530
00:25:15,430 --> 00:25:11,120
so what you're looking at here

531
00:25:17,909 --> 00:25:15,440
on the top left that's a typical

532
00:25:19,350 --> 00:25:17,919
called atom laboratory

533
00:25:21,750 --> 00:25:19,360
here on earth

534
00:25:22,870 --> 00:25:21,760
you see lasers

535
00:25:24,549 --> 00:25:22,880
electronic

536
00:25:26,070 --> 00:25:24,559
for controlling

537
00:25:29,750 --> 00:25:26,080
optics

538
00:25:31,669 --> 00:25:29,760

the ultra vacuum

539
00:25:34,470 --> 00:25:31,679
there these types of experiments are

540
00:25:37,590 --> 00:25:34,480
considered the most complex

541
00:25:39,590 --> 00:25:37,600
uh tabletop experiments on earth

542
00:25:42,789 --> 00:25:39,600
and what you don't see here actually it

543
00:25:45,830 --> 00:25:42,799
usually requires multiple people to run

544
00:25:48,310 --> 00:25:45,840
this kind of experiments because

545
00:25:50,310 --> 00:25:48,320
they're really hard to keep running

546
00:25:52,310 --> 00:25:50,320
smoothly and and if i'm saying this

547
00:25:55,590 --> 00:25:52,320
because i've had a chance to talk to so

548
00:25:58,230 --> 00:25:55,600
many physicists and and they acknowledge

549
00:26:01,669 --> 00:25:58,240
this and the challenge we had

550
00:26:02,789 --> 00:26:01,679
and this is almost like to to to

551
00:26:04,470 --> 00:26:02,799
to scale

552
00:26:06,310 --> 00:26:04,480
is basically

553
00:26:10,470 --> 00:26:06,320
take all this stuff

554
00:26:13,350 --> 00:26:10,480
and make it fit in a small box on top of

555
00:26:14,230 --> 00:26:13,360
this it has you had to

556
00:26:17,510 --> 00:26:14,240
be

557
00:26:20,230 --> 00:26:17,520
operated remotely

558
00:26:26,149 --> 00:26:22,789
some of this

559
00:26:29,590 --> 00:26:26,159
you know challenges also involved

560
00:26:31,350 --> 00:26:29,600
how we would deal with the repairs

561
00:26:33,430 --> 00:26:31,360
so in a sense

562
00:26:35,510 --> 00:26:33,440
it took a lot of

563
00:26:38,070 --> 00:26:35,520

hard-working people and especially i see

564
00:26:40,149 --> 00:26:38,080
around like students so many disciplines

565
00:26:44,390 --> 00:26:40,159
electrical engineers

566
00:26:46,789 --> 00:26:44,400
mechanical systems thermal it takes many

567
00:26:49,669 --> 00:26:46,799
different disciplines to to make a

568
00:26:52,390 --> 00:26:49,679
mission like cal successful and we've

569
00:26:54,549 --> 00:26:52,400
been as you heard operating

570
00:26:56,950 --> 00:26:54,559
in space for four years

571
00:27:00,630 --> 00:26:56,960
and luckily the the idea of the design

572
00:27:02,549 --> 00:27:00,640
of this modular approach also has uh

573
00:27:04,950 --> 00:27:02,559
helped us a lot and in a little bit of

574
00:27:07,669 --> 00:27:04,960
time so what you see here uh it's the

575
00:27:09,430 --> 00:27:07,679
same uh part of the instrument of the

576
00:27:10,950 --> 00:27:09,440
science instrument that's this that's

577
00:27:13,430 --> 00:27:10,960
the science

578
00:27:16,390 --> 00:27:13,440
uh module and that's where all the

579
00:27:18,870 --> 00:27:16,400
science happens and at the heart of this

580
00:27:21,510 --> 00:27:18,880
uh science module there is the physics

581
00:27:23,590 --> 00:27:21,520
package and this uh

582
00:27:25,590 --> 00:27:23,600
ultra sensitive vacuum as i mentioned

583
00:27:26,950 --> 00:27:25,600
and we did it in collaboration with with

584
00:27:29,909 --> 00:27:26,960
our

585
00:27:31,750 --> 00:27:29,919
partner uh cole quanta

586
00:27:35,350 --> 00:27:31,760
played an important role also in the

587
00:27:38,789 --> 00:27:35,360
success of cal

588
00:27:42,389 --> 00:27:38,799

so you heard uh john quickly mentioned

589
00:27:44,149 --> 00:27:42,399
about the the fact that why space i mean

590
00:27:46,950 --> 00:27:44,159
you can think of it like when you see

591
00:27:49,909 --> 00:27:46,960
astronauts floating right that's the

592
00:27:51,909 --> 00:27:49,919
same kind of idea what happens when we

593
00:27:53,909 --> 00:27:51,919
call atoms so

594
00:27:56,470 --> 00:27:53,919
when they float

595
00:27:58,549 --> 00:27:56,480
we get to observe them at longer period

596
00:28:00,789 --> 00:27:58,559
of time so basically the bose einstein

597
00:28:03,430 --> 00:28:00,799
condensate have been produced on earth

598
00:28:05,590 --> 00:28:03,440
and actually the first person to ever do

599
00:28:09,990 --> 00:28:05,600
it is here with us this is professor

600
00:28:11,190 --> 00:28:10,000
eric cornell on the ground 1985 and the

601
00:28:14,310 --> 00:28:11,200
idea

602
00:28:16,470 --> 00:28:14,320
is because of gravity uh it limits the

603
00:28:19,990 --> 00:28:16,480
the amount of time that we can observe

604
00:28:22,630 --> 00:28:20,000
this this uh ultra cold atom so by going

605
00:28:27,350 --> 00:28:22,640
to space it helps us

606
00:28:29,590 --> 00:28:27,360
to observe it at longer time and also

607
00:28:33,110 --> 00:28:29,600
this kind of sensors that just john

608
00:28:35,669 --> 00:28:33,120
talked about dark matter dark energy

609
00:28:38,630 --> 00:28:35,679
on top of this there's some applications

610
00:28:40,950 --> 00:28:38,640
especially we here at jpl we're so

611
00:28:42,230 --> 00:28:40,960
involved in planetary science so it can

612
00:28:44,389 --> 00:28:42,240
improve

613
00:28:47,909 --> 00:28:44,399

sensors for navigation

614
00:28:49,990 --> 00:28:47,919
and also um you know for gravity and and

615
00:28:51,110 --> 00:28:50,000
understanding interest structures of

616
00:28:54,470 --> 00:28:51,120
planets

617
00:28:58,870 --> 00:28:54,480
and uh additionally it can even help us

618
00:29:00,310 --> 00:28:58,880
uh study earth's climate

619
00:29:02,389 --> 00:29:00,320
and

620
00:29:04,230 --> 00:29:02,399
sorry

621
00:29:07,430 --> 00:29:04,240
so what you're seeing that's like a

622
00:29:10,470 --> 00:29:07,440
cloud of atoms we usually use lasers to

623
00:29:13,590 --> 00:29:10,480
slow down the atoms and then also we use

624
00:29:14,470 --> 00:29:13,600
magnetic traps to control them

625
00:29:18,789 --> 00:29:14,480
and

626
00:29:20,630 --> 00:29:18,799
magnetic traps

627
00:29:22,789 --> 00:29:20,640
allows us to

628
00:29:24,230 --> 00:29:22,799
reach lower temperatures in microgravity

629
00:29:26,789 --> 00:29:24,240
compared to earth

630
00:29:29,110 --> 00:29:26,799
all right so what you're looking here

631
00:29:30,950 --> 00:29:29,120
and this is not something i'm going to

632
00:29:35,110 --> 00:29:30,960
go over because that's going to be like

633
00:29:37,669 --> 00:29:35,120
the focus of professor eric cornell's um

634
00:29:39,590 --> 00:29:37,679
talk but this is just the bose einstein

635
00:29:41,669 --> 00:29:39,600
condensate so would like you to remember

636
00:29:44,070 --> 00:29:41,679
from this first

637
00:29:45,510 --> 00:29:44,080
bose and einstein

638
00:29:48,549 --> 00:29:45,520

thought about this

639
00:29:49,909 --> 00:29:48,559
almost 100 years ago in 1920s

640
00:29:53,430 --> 00:29:49,919
and they they

641
00:29:55,190 --> 00:29:53,440
published a paper that if you can cool

642
00:29:58,549 --> 00:29:55,200
atoms to very

643
00:30:01,269 --> 00:29:58,559
ultra cold temperatures

644
00:30:02,710 --> 00:30:01,279
these particles start behaving like

645
00:30:04,549 --> 00:30:02,720
waves

646
00:30:06,549 --> 00:30:04,559
and

647
00:30:08,630 --> 00:30:06,559
if you

648
00:30:11,190 --> 00:30:08,640
lower their temperature further

649
00:30:13,750 --> 00:30:11,200
these waves combine or collapse in a

650
00:30:15,110 --> 00:30:13,760
single wave and uh

651
00:30:16,870 --> 00:30:15,120
they become they both einstein

652
00:30:18,230 --> 00:30:16,880
condensate

653
00:30:20,950 --> 00:30:18,240
and

654
00:30:23,190 --> 00:30:20,960
the idea this you can think of it like a

655
00:30:27,430 --> 00:30:23,200
it's a different form of state of matter

656
00:30:27,440 --> 00:30:29,830
and

657
00:30:32,389 --> 00:30:30,950
solids

658
00:30:34,149 --> 00:30:32,399
and plasma

659
00:30:36,230 --> 00:30:34,159
this is the fifth state of matter it's

660
00:30:37,990 --> 00:30:36,240
both einstein columnist why this is

661
00:30:41,190 --> 00:30:38,000
important because think of the called

662
00:30:43,269 --> 00:30:41,200
adam lab every day when our team shows

663
00:30:44,789 --> 00:30:43,279

up to the

664
00:30:47,909 --> 00:30:44,799
operations room

665
00:30:50,470 --> 00:30:47,919
their idea or their primary objective is

666
00:30:53,350 --> 00:30:50,480
to make the machine or the cold atom lab

667
00:30:54,789 --> 00:30:53,360
create these bose einstein condensates

668
00:30:57,590 --> 00:30:54,799
which

669
00:30:59,750 --> 00:30:57,600
almost like looking

670
00:31:03,430 --> 00:30:59,760
at a

671
00:31:05,990 --> 00:31:03,440
quantum in a macroscopic level

672
00:31:09,029 --> 00:31:06,000
and they use this bose einstein

673
00:31:11,990 --> 00:31:09,039
condensate to do their science so

674
00:31:13,029 --> 00:31:12,000
we have we're supporting about five

675
00:31:14,710 --> 00:31:13,039
uh

676
00:31:16,389 --> 00:31:14,720
science teams

677
00:31:19,110 --> 00:31:16,399
and the idea is

678
00:31:21,750 --> 00:31:19,120
they expect us to to produce this uh

679
00:31:24,789 --> 00:31:21,760
level of bose einstein constant and they

680
00:31:27,029 --> 00:31:24,799
use this interesting matter as i said to

681
00:31:29,269 --> 00:31:27,039
to do their experiment and just because

682
00:31:31,430 --> 00:31:29,279
five teams are working on cal right now

683
00:31:33,190 --> 00:31:31,440
that doesn't mean that we can have more

684
00:31:35,430 --> 00:31:33,200
many people

685
00:31:37,350 --> 00:31:35,440
use the same kind of

686
00:31:39,750 --> 00:31:37,360
fifth state of matter to to create their

687
00:31:41,750 --> 00:31:39,760
own experiments in the future

688
00:31:44,230 --> 00:31:41,760

and um

689
00:31:48,870 --> 00:31:44,240
and that sums up what i wanted to say

690
00:31:48,880 --> 00:31:52,950
take a minute to introduce

691
00:31:52,960 --> 00:31:57,190
our

692
00:31:59,590 --> 00:31:58,549
distinguished

693
00:32:01,909 --> 00:31:59,600
guest

694
00:32:03,590 --> 00:32:01,919
uh christina

695
00:32:05,590 --> 00:32:03,600
coke uh

696
00:32:08,389 --> 00:32:05,600
but i think i just want to make sure

697
00:32:11,029 --> 00:32:08,399
actually christina cook right that's how

698
00:32:11,830 --> 00:32:11,039
you prefer yeah okay um

699
00:32:13,269 --> 00:32:11,840
so

700
00:32:15,269 --> 00:32:13,279
chris

701
00:32:20,230 --> 00:32:15,279
i'm a little struggling with the light

702
00:32:21,669 --> 00:32:20,240
but uh okay christina holds a

703
00:32:22,950 --> 00:32:21,679
bachelor's degree in electrical

704
00:32:25,430 --> 00:32:22,960
engineering

705
00:32:27,350 --> 00:32:25,440
and physics

706
00:32:29,269 --> 00:32:27,360
and a master's degree in electrical

707
00:32:31,190 --> 00:32:29,279
engineering from northern california

708
00:32:34,070 --> 00:32:31,200
state

709
00:32:36,870 --> 00:32:34,080
prior to becoming astronaut

710
00:32:39,509 --> 00:32:36,880
her career spanned two areas remote

711
00:32:42,230 --> 00:32:39,519
scientific field engineering and space

712
00:32:45,029 --> 00:32:42,240
science instrument development including

713
00:32:47,750 --> 00:32:45,039

her work at the nasa goddard space

714
00:32:49,190 --> 00:32:47,760
flight center laboratory for high energy

715
00:32:51,190 --> 00:32:49,200
astrophysics

716
00:32:53,350 --> 00:32:51,200
where she contributed to scientific

717
00:32:54,870 --> 00:32:53,360
instruments on several nasa space

718
00:32:57,509 --> 00:32:54,880
science missions

719
00:33:00,310 --> 00:32:57,519
and actually i found out that juno was

720
00:33:02,230 --> 00:33:00,320
par part of this nasa missions

721
00:33:04,310 --> 00:33:02,240
in june 2013

722
00:33:07,110 --> 00:33:04,320
christina was selected

723
00:33:08,950 --> 00:33:07,120
as one of the eight members of the 21st

724
00:33:11,750 --> 00:33:08,960
nasa astronaut class

725
00:33:14,870 --> 00:33:11,760
in 2018 she was assigned to her first

726
00:33:17,830 --> 00:33:14,880
space flight a long duration mission on

727
00:33:20,149 --> 00:33:17,840
the international space station

728
00:33:24,710 --> 00:33:20,159
she was a part of iss

729
00:33:27,669 --> 00:33:24,720
expeditions 59 60 and 61. she has

730
00:33:30,549 --> 00:33:27,679
conducted six spacewalks including the

731
00:33:33,269 --> 00:33:30,559
first three all-women spacewalks

732
00:33:35,669 --> 00:33:33,279
totaling 42 hours and 15 minutes

733
00:33:38,470 --> 00:33:35,679
christina has also set a record for the

734
00:33:42,710 --> 00:33:38,480
longest single space flight by a woman

735
00:33:44,630 --> 00:33:42,720
with a total of 328 days in space

736
00:33:47,509 --> 00:33:44,640
throughout her career

737
00:33:49,909 --> 00:33:47,519
she has been involved in the electrical

738
00:33:53,110 --> 00:33:49,919

uh sorry technical instructing

739
00:33:54,310 --> 00:33:53,120
volunteers tutoring and educational

740
00:33:56,149 --> 00:33:54,320
outreach

741
00:33:58,310 --> 00:33:56,159
she also enjoys a wide range of

742
00:33:59,830 --> 00:33:58,320
activities including

743
00:34:02,950 --> 00:33:59,840
backpacking

744
00:34:06,389 --> 00:34:02,960
rock climbing puddling surfing running

745
00:34:07,990 --> 00:34:06,399
yoga community service photography which

746
00:34:11,990 --> 00:34:08,000
we've seen some of your amazing

747
00:34:15,909 --> 00:34:12,000
photography photo photographs and travel

748
00:34:20,869 --> 00:34:17,990
please

749
00:34:21,829 --> 00:34:20,879
let's welcome christina

750
00:34:23,669 --> 00:34:21,839
coke

751
00:34:26,550 --> 00:34:23,679
but before

752
00:34:28,710 --> 00:34:26,560
we have a little surprise for her

753
00:34:30,550 --> 00:34:28,720
and i want to just give you a little

754
00:34:32,710 --> 00:34:30,560
perspective because you've heard about

755
00:34:34,950 --> 00:34:32,720
the upgrade to the cow

756
00:34:37,909 --> 00:34:34,960
because the cold atom lab when it was

757
00:34:40,470 --> 00:34:37,919
launched it was it did not include atom

758
00:34:42,310 --> 00:34:40,480
interferometry which is a like john

759
00:34:44,790 --> 00:34:42,320
mentioned it's a critical

760
00:34:46,149 --> 00:34:44,800
part of our science tools to help us

761
00:34:50,869 --> 00:34:46,159
study the

762
00:34:51,750 --> 00:34:50,879
struggle

763
00:34:57,829 --> 00:34:51,760

um

764
00:35:00,390 --> 00:34:57,839
and uh do the the upgrade here and that

765
00:35:04,630 --> 00:35:00,400
was like some people highly recommend

766
00:35:06,950 --> 00:35:04,640
that we do this or we turn uh and rely

767
00:35:08,230 --> 00:35:06,960
and put our fates in the hand of

768
00:35:09,990 --> 00:35:08,240
astronauts

769
00:35:11,829 --> 00:35:10,000
and uh

770
00:35:13,190 --> 00:35:11,839
see if it can work

771
00:35:15,190 --> 00:35:13,200
but we did

772
00:35:17,190 --> 00:35:15,200
we were told it was going to be 50

773
00:35:19,030 --> 00:35:17,200
chance

774
00:35:21,510 --> 00:35:19,040
sorry but the problem had we brought it

775
00:35:24,790 --> 00:35:21,520
back it would take we would be down for

776
00:35:28,550 --> 00:35:24,800
at least two years on the ground

777
00:35:31,349 --> 00:35:28,560
we our stars uh lined up lucky star so

778
00:35:34,710 --> 00:35:31,359
to speak and we

779
00:35:36,470 --> 00:35:34,720
were so lucky to have uh astronaut

780
00:35:37,829 --> 00:35:36,480
christina cook

781
00:35:39,589 --> 00:35:37,839
who

782
00:35:41,270 --> 00:35:39,599
when we

783
00:35:43,510 --> 00:35:41,280
looked at all the work she had done we

784
00:35:45,030 --> 00:35:43,520
knew that we had a good chance

785
00:35:46,870 --> 00:35:45,040
and

786
00:35:49,670 --> 00:35:46,880
we watch her

787
00:35:52,470 --> 00:35:49,680
we work you know like from the ground

788
00:35:55,109 --> 00:35:52,480

and she did an amazing job

789
00:35:56,230 --> 00:35:55,119
and and we and once again as i said we

790
00:35:58,790 --> 00:35:56,240
had no

791
00:36:01,030 --> 00:35:58,800
there is no uh chance for

792
00:36:02,790 --> 00:36:01,040
any errors or anything because it's a

793
00:36:05,030 --> 00:36:02,800
science instrument which means it's a

794
00:36:07,829 --> 00:36:05,040
single string like there is no

795
00:36:08,710 --> 00:36:07,839
redundancy and she did it in a record

796
00:36:12,230 --> 00:36:08,720
time

797
00:36:14,950 --> 00:36:12,240
and because of her amazing work we would

798
00:36:18,950 --> 00:36:14,960
like to take a moment on behalf of

799
00:36:20,710 --> 00:36:18,960
jpl to thank her for all her exceptional

800
00:36:24,550 --> 00:36:20,720
work and i'm going to read the plaque

801
00:36:28,550 --> 00:36:24,560
and i will ask our doctor

802
00:36:31,910 --> 00:36:28,560
claire patel uh director for astronomy

803
00:36:34,150 --> 00:36:31,920
physics to hand her

804
00:36:35,750 --> 00:36:34,160
this plaque but i just want to go ahead

805
00:36:37,190 --> 00:36:35,760
and read it if you allow me

806
00:36:39,510 --> 00:36:37,200
presented

807
00:36:41,589 --> 00:36:39,520
to astronaut christina koch

808
00:36:43,829 --> 00:36:41,599
for your exceptional support to enable

809
00:36:46,230 --> 00:36:43,839
the upgrade of the called adam lab with

810
00:36:47,910 --> 00:36:46,240
adam interferometry in space from your

811
00:36:50,080 --> 00:36:47,920
friends at nasa's jet propulsion

812
00:37:00,390 --> 00:36:50,090
laboratory

813
00:37:10,470 --> 00:37:00,400

[Applause]

814
00:37:10,480 --> 00:37:20,950
okay sorry so let me take a picture

815
00:37:26,630 --> 00:37:23,510
thank you thank you kamal this is just

816
00:37:28,710 --> 00:37:26,640
such an honor and such a a surprise i

817
00:37:30,870 --> 00:37:28,720
feel like i was the one that my lucky

818
00:37:33,670 --> 00:37:30,880
stars aligned so that i could be a part

819
00:37:35,510 --> 00:37:33,680
of cold adam lab and actually what i'm

820
00:37:37,670 --> 00:37:35,520
going to talk about today is is that

821
00:37:40,710 --> 00:37:37,680
whole story so i won't go into it now

822
00:37:43,190 --> 00:37:40,720
but it is such an honor to be here with

823
00:37:44,550 --> 00:37:43,200
you all to share this stage with these

824
00:37:46,950 --> 00:37:44,560
amazing people

825
00:37:49,670 --> 00:37:46,960
and just to be in your presence i

826
00:37:52,150 --> 00:37:49,680
definitely let my nerd flag fly often

827
00:37:54,310 --> 00:37:52,160
and jpl has always been a place that was

828
00:37:56,150 --> 00:37:54,320
kind of a beacon for me

829
00:37:57,990 --> 00:37:56,160
in that regard and it's just any time i

830
00:37:59,589 --> 00:37:58,000
can get here is a wonderful day and

831
00:38:00,870 --> 00:37:59,599
anytime i can work with the teams here

832
00:38:04,069 --> 00:38:00,880
is even better

833
00:38:05,829 --> 00:38:04,079
so often times when i speak i i just

834
00:38:07,109 --> 00:38:05,839
talk about my mission my journey how i

835
00:38:09,829 --> 00:38:07,119
got to space

836
00:38:12,710 --> 00:38:09,839
um and today it's a little bit more

837
00:38:14,069 --> 00:38:12,720
targeted i'm going to talk about how i

838
00:38:15,750 --> 00:38:14,079

became

839
00:38:18,870 --> 00:38:15,760
the space

840
00:38:20,790 --> 00:38:18,880
cold adam lab repair guy

841
00:38:22,870 --> 00:38:20,800
that was the real journey that was going

842
00:38:24,950 --> 00:38:22,880
on it turns out my entire career and i'm

843
00:38:27,349 --> 00:38:24,960
going to show you why

844
00:38:29,430 --> 00:38:27,359
so i started a straight out of college

845
00:38:32,470 --> 00:38:29,440
at goddard space flight center in a lab

846
00:38:35,349 --> 00:38:32,480
that did super conducting uh sensors for

847
00:38:36,870 --> 00:38:35,359
astrophysics and i had to learn how to

848
00:38:38,950 --> 00:38:36,880
work with liquid helium and liquid

849
00:38:41,829 --> 00:38:38,960
nitrogen and so this was back in the day

850
00:38:44,150 --> 00:38:41,839
when i thought 4 kelvin was cold maybe 6

851
00:38:46,230 --> 00:38:44,160
3 micro kelvin was cold

852
00:38:49,109 --> 00:38:46,240
that obviously all changed throughout my

853
00:38:51,430 --> 00:38:49,119
journey um and actually it started even

854
00:38:54,230 --> 00:38:51,440
before this because when i was in grad

855
00:38:56,069 --> 00:38:54,240
school i actually got to do all of those

856
00:38:58,230 --> 00:38:56,079
wave equations for

857
00:39:00,550 --> 00:38:58,240
bose-einstein condensates and i remember

858
00:39:03,670 --> 00:39:00,560
thinking at that time wow

859
00:39:06,630 --> 00:39:03,680
i'm never going to use this

860
00:39:09,030 --> 00:39:06,640
but i'm i i have to report that after

861
00:39:11,270 --> 00:39:09,040
having worked on cold adam lab

862
00:39:15,030 --> 00:39:11,280
i still have never used it

863
00:39:16,710 --> 00:39:15,040

but i at least knew how to spell um bcs

864
00:39:19,750 --> 00:39:16,720
by then because i had done that work in

865
00:39:21,750 --> 00:39:19,760
grad school um but it turns out after

866
00:39:24,390 --> 00:39:21,760
working in a laboratory on earth that

867
00:39:26,230 --> 00:39:24,400
did a lot of cryogenics i needed to then

868
00:39:27,750 --> 00:39:26,240
be at the coldest place on earth so i

869
00:39:29,270 --> 00:39:27,760
worked at the south pole station in

870
00:39:31,030 --> 00:39:29,280
antarctica for a while this is where

871
00:39:33,270 --> 00:39:31,040
science on the frontiers really first

872
00:39:35,829 --> 00:39:33,280
started energizing what would become my

873
00:39:38,230 --> 00:39:35,839
career path and i was actually the

874
00:39:40,230 --> 00:39:38,240
cryogenics technician of the south pole

875
00:39:42,630 --> 00:39:40,240
station our motto was when the south

876
00:39:45,510 --> 00:39:42,640
pole just isn't cold enough come to us

877
00:39:47,349 --> 00:39:45,520
and we did have a liquid helium thing

878
00:39:49,829 --> 00:39:47,359
again to enable astrophysics that

879
00:39:52,310 --> 00:39:49,839
happens there

880
00:39:54,069 --> 00:39:52,320
i worked in some missions at the applied

881
00:39:56,630 --> 00:39:54,079
physics lab always with the space

882
00:39:59,589 --> 00:39:56,640
science and instrumentation in mind and

883
00:40:02,150 --> 00:39:59,599
oftentimes also in very cold places and

884
00:40:04,790 --> 00:40:02,160
that's when i found myself here having

885
00:40:08,150 --> 00:40:04,800
been selected as a very lucky member of

886
00:40:10,230 --> 00:40:08,160
the 2013 astronaut class and soon after

887
00:40:12,309 --> 00:40:10,240
we got started into our what we call

888
00:40:13,990 --> 00:40:12,319

astronaut candidate training so this was

889
00:40:15,430 --> 00:40:14,000
where i learned a whole lot of different

890
00:40:17,430 --> 00:40:15,440
career paths and things that i would

891
00:40:19,190 --> 00:40:17,440
have to do to eventually be the cold

892
00:40:22,309 --> 00:40:19,200
adam lab repair guy

893
00:40:24,390 --> 00:40:22,319
including how to fly a supersonic jet

894
00:40:25,910 --> 00:40:24,400
how to do space walking which we learn

895
00:40:27,349 --> 00:40:25,920
in our gigantic

896
00:40:29,430 --> 00:40:27,359
pool facility called the neutral

897
00:40:31,270 --> 00:40:29,440
buoyancy lab that has an entire mock-up

898
00:40:33,430 --> 00:40:31,280
of the space station underwater so that

899
00:40:36,230 --> 00:40:33,440
we can practice this work

900
00:40:38,470 --> 00:40:36,240
and even during our time learning how to

901
00:40:40,150 --> 00:40:38,480
become astronauts my astronaut class got

902
00:40:42,390 --> 00:40:40,160
to visit jpl so that was a really

903
00:40:44,230 --> 00:40:42,400
exciting time we saw the mars yard we

904
00:40:45,589 --> 00:40:44,240
got to do the fundamental physics tour

905
00:40:46,870 --> 00:40:45,599
as well

906
00:40:48,309 --> 00:40:46,880
and eventually i got my flight

907
00:40:49,990 --> 00:40:48,319
assignment and that's when we go into

908
00:40:51,990 --> 00:40:50,000
flight specific

909
00:40:53,910 --> 00:40:52,000
training this is us training on some of

910
00:40:55,430 --> 00:40:53,920
the other science that we do onboard the

911
00:40:57,109 --> 00:40:55,440
space station

912
00:40:59,030 --> 00:40:57,119
and this is actually the first time i

913
00:41:01,109 --> 00:40:59,040

learned about cold adam lab and i

914
00:41:02,470 --> 00:41:01,119
remember thinking wow if i get to work

915
00:41:04,309 --> 00:41:02,480
on that when i'm up there that would be

916
00:41:06,630 --> 00:41:04,319
really cool think of everything i've

917
00:41:07,510 --> 00:41:06,640
done this is the obvious next step for

918
00:41:12,309 --> 00:41:07,520
me

919
00:41:13,910 --> 00:41:12,319
claims and is the coldest spot in the

920
00:41:15,910 --> 00:41:13,920
universe so that was that was an

921
00:41:17,829 --> 00:41:15,920
exciting possibility but i was told that

922
00:41:19,430 --> 00:41:17,839
no one ever really works on that that's

923
00:41:20,870 --> 00:41:19,440
something that astronauts don't actually

924
00:41:22,870 --> 00:41:20,880
get to interact with because as you've

925
00:41:25,349 --> 00:41:22,880
learned the experts usually can run it

926
00:41:27,589 --> 00:41:25,359
directly from the ground and so i knew

927
00:41:29,670 --> 00:41:27,599
that i would have to get really lucky

928
00:41:31,430 --> 00:41:29,680
and have an opportunity for an upgrade

929
00:41:33,589 --> 00:41:31,440
or something like that

930
00:41:35,430 --> 00:41:33,599
kept on training i was an astronaut that

931
00:41:37,510 --> 00:41:35,440
launched on a soyuz rocket out of

932
00:41:39,109 --> 00:41:37,520
kazakhstan it's a russian rocket so part

933
00:41:42,150 --> 00:41:39,119
of my training and actually quite a bit

934
00:41:45,430 --> 00:41:42,160
of it was in russia and then came this

935
00:41:52,069 --> 00:41:48,950
the actual launch day and

936
00:41:53,750 --> 00:41:52,079
eight minutes later finding yourself

937
00:41:55,750 --> 00:41:53,760
in microgravity

938
00:41:58,150 --> 00:41:55,760

when that third stage cuts off and you

939
00:41:59,109 --> 00:41:58,160
float a little bit out of your seat and

940
00:42:03,270 --> 00:41:59,119
you know

941
00:42:05,589 --> 00:42:03,280
you are one step closer to cold adam lab

942
00:42:07,589 --> 00:42:05,599
the spacecraft obviously becomes a free

943
00:42:09,270 --> 00:42:07,599
flyer for just a little while we end up

944
00:42:10,630 --> 00:42:09,280
at the space station about six hours

945
00:42:13,990 --> 00:42:10,640
after launch if you can believe it it's

946
00:42:16,470 --> 00:42:14,000
pretty quick and that

947
00:42:18,950 --> 00:42:16,480
hatch here is what actually docks and

948
00:42:21,829 --> 00:42:18,960
it's the hatch that we open to enter the

949
00:42:24,309 --> 00:42:21,839
space station and meet our friends

950
00:42:25,990 --> 00:42:24,319
so life on board is a lot of

951
00:42:27,270 --> 00:42:26,000
it's a combination of a lot of things

952
00:42:28,870 --> 00:42:27,280
obviously we all know that the main

953
00:42:30,870 --> 00:42:28,880
mission of the space station is to be a

954
00:42:32,630 --> 00:42:30,880
national lab that does the science that

955
00:42:34,630 --> 00:42:32,640
can only be done in that space

956
00:42:36,309 --> 00:42:34,640
environment but to keep it running that

957
00:42:38,710 --> 00:42:36,319
involves a lot of maintenance most of

958
00:42:40,550 --> 00:42:38,720
which is on you know racks that do all

959
00:42:41,910 --> 00:42:40,560
of our life support systems all of our

960
00:42:43,670 --> 00:42:41,920
avionics

961
00:42:45,430 --> 00:42:43,680
sometimes we get lucky and for an

962
00:42:47,109 --> 00:42:45,440
electrical engineer we get to do some of

963
00:42:49,670 --> 00:42:47,119

the board level

964
00:42:51,589 --> 00:42:49,680
work and and repair this is one example

965
00:42:53,990 --> 00:42:51,599
of those times

966
00:42:55,990 --> 00:42:54,000
and then other things when visiting

967
00:42:58,390 --> 00:42:56,000
cargo vehicles come we actually operate

968
00:42:59,430 --> 00:42:58,400
the robotic arm to bring them aboard and

969
00:43:01,349 --> 00:42:59,440
to make sure that we can get those

970
00:43:03,349 --> 00:43:01,359
supplies some of which are the new

971
00:43:05,829 --> 00:43:03,359
science experiments

972
00:43:08,870 --> 00:43:05,839
and of course spacewalking so this is uh

973
00:43:11,430 --> 00:43:08,880
jessica mir and i who we were honored to

974
00:43:13,270 --> 00:43:11,440
be uh the the two astronauts that got to

975
00:43:15,109 --> 00:43:13,280
do the first ever spacewalk that was

976
00:43:17,190 --> 00:43:15,119
conducted by two women first of all

977
00:43:19,670 --> 00:43:17,200
female spacewalk and we got to go out

978
00:43:22,069 --> 00:43:19,680
and do that three times together

979
00:43:24,150 --> 00:43:22,079
and that is truly just one of the gems

980
00:43:25,910 --> 00:43:24,160
for any astronaut being able to enable

981
00:43:27,910 --> 00:43:25,920
the space you know the science to

982
00:43:30,069 --> 00:43:27,920
continue on the space station by

983
00:43:31,829 --> 00:43:30,079
upgrading and repairing the outside of

984
00:43:33,270 --> 00:43:31,839
the space station

985
00:43:35,589 --> 00:43:33,280
we also love the international

986
00:43:37,430 --> 00:43:35,599
collaborative uh aspect of the space

987
00:43:39,589 --> 00:43:37,440
station it's one in my opinion of its

988
00:43:41,510 --> 00:43:39,599

its loftiest goals and its loftiest

989
00:43:43,430 --> 00:43:41,520
achievements and this is me working with

990
00:43:45,109 --> 00:43:43,440
my actual russian commander alexei of

991
00:43:48,630 --> 00:43:45,119
chinen preparing for one of his

992
00:43:49,750 --> 00:43:48,640
spacewalks that i got to help with

993
00:43:52,630 --> 00:43:49,760
and now

994
00:43:55,990 --> 00:43:52,640
a little bit about the science so this

995
00:43:57,589 --> 00:43:56,000
is a video um that we put together as a

996
00:43:59,030 --> 00:43:57,599
compilation of a lot of the different

997
00:44:00,710 --> 00:43:59,040
science and i'm going to narrate it the

998
00:44:03,190 --> 00:44:00,720
actual video has some music so bear with

999
00:44:05,589 --> 00:44:03,200
me one of the life sciences experiments

1000
00:44:07,589 --> 00:44:05,599
that we do is the plant work and in this

1001
00:44:09,510 --> 00:44:07,599
video you hear me enter talking back and

1002
00:44:11,190 --> 00:44:09,520
forth with the folks on the ground about

1003
00:44:12,550 --> 00:44:11,200
how much water to actually put in each

1004
00:44:13,990 --> 00:44:12,560
of the plants

1005
00:44:15,750 --> 00:44:14,000
and one of my favorite things about

1006
00:44:17,510 --> 00:44:15,760
working in space is you feel like you

1007
00:44:20,150 --> 00:44:17,520
have your lab partner on the ground and

1008
00:44:21,430 --> 00:44:20,160
you really have a great relationship

1009
00:44:24,550 --> 00:44:21,440
with that person that you're working

1010
00:44:26,790 --> 00:44:24,560
with um i got to talk to jim jim kellogg

1011
00:44:28,790 --> 00:44:26,800
from this cold adam lab

1012
00:44:31,109 --> 00:44:28,800
for for days working on working on it

1013
00:44:33,910 --> 00:44:31,119

together and you really you you get to

1014
00:44:35,670 --> 00:44:33,920
feel like you are a part of that team

1015
00:44:37,349 --> 00:44:35,680
jessica and i again working on our plant

1016
00:44:39,510 --> 00:44:37,359
lab

1017
00:44:41,190 --> 00:44:39,520
this is an experiment with tissue chips

1018
00:44:43,589 --> 00:44:41,200
so actually doing some biological

1019
00:44:45,430 --> 00:44:43,599
experiments on a chip that's able to

1020
00:44:47,109 --> 00:44:45,440
represent some of the mechanics of our

1021
00:44:49,030 --> 00:44:47,119
of our biological systems that we're

1022
00:44:51,109 --> 00:44:49,040
studying and of course

1023
00:44:52,710 --> 00:44:51,119
the cold adam lab when i got there i

1024
00:44:54,069 --> 00:44:52,720
made my buddy get out the camera and

1025
00:44:55,510 --> 00:44:54,079
take pictures of me because at that

1026
00:44:57,430 --> 00:44:55,520
point i didn't even know if i was going

1027
00:44:59,030 --> 00:44:57,440
to get to work on it or not i was just

1028
00:45:01,670 --> 00:44:59,040
excited to see the label on the outside

1029
00:45:05,990 --> 00:45:03,750
and this is a really neat experiment

1030
00:45:09,190 --> 00:45:06,000
where we were actually doing biological

1031
00:45:11,109 --> 00:45:09,200
printing so a experiment that again

1032
00:45:12,550 --> 00:45:11,119
utilizes that microgravity environment

1033
00:45:15,030 --> 00:45:12,560
to build up

1034
00:45:17,270 --> 00:45:15,040
3d models of what we hope one day could

1035
00:45:19,589 --> 00:45:17,280
be actual organs and there i am getting

1036
00:45:21,510 --> 00:45:19,599
started on cold adam lab one day

1037
00:45:24,630 --> 00:45:21,520
combustion experiments flame sperm

1038
00:45:26,710 --> 00:45:24,640

spherical in space um everything you can

1039
00:45:27,750 --> 00:45:26,720
imagine and i think the last sequence

1040
00:45:29,430 --> 00:45:27,760
here

1041
00:45:30,309 --> 00:45:29,440
oh this is actually a great sequence

1042
00:45:31,510 --> 00:45:30,319
where

1043
00:45:34,069 --> 00:45:31,520
it shows

1044
00:45:35,589 --> 00:45:34,079
someone had noticed from the ground with

1045
00:45:38,550 --> 00:45:35,599
the over-the-shoulder video that i had

1046
00:45:41,349 --> 00:45:38,560
forgot to cap um one of their cell

1047
00:45:43,910 --> 00:45:41,359
cultures and it was just again another

1048
00:45:47,109 --> 00:45:43,920
example of how fun it is to to have that

1049
00:45:51,030 --> 00:45:47,119
team work with people on the ground

1050
00:45:54,069 --> 00:45:51,040
automated tech demonstration experiments

1051
00:45:56,390 --> 00:45:54,079
and a lot of how cellular organisms

1052
00:45:57,750 --> 00:45:56,400
react to the microgravity environment a

1053
00:45:59,990 --> 00:45:57,760
lot of people ask me what kind of

1054
00:46:03,109 --> 00:46:00,000
science do you do on iss and i say it's

1055
00:46:04,950 --> 00:46:03,119
it's not one kind it's just the kind

1056
00:46:07,109 --> 00:46:04,960
that you can't do anywhere else and

1057
00:46:14,230 --> 00:46:07,119
anything that qualifies we do it up

1058
00:46:19,109 --> 00:46:17,030
so um since we're in the nest and this

1059
00:46:21,510 --> 00:46:19,119
is a small group i thought i'd share

1060
00:46:23,670 --> 00:46:21,520
that this picture that is one that i

1061
00:46:26,550 --> 00:46:23,680
love so much actually was not as easy to

1062
00:46:28,309 --> 00:46:26,560
take as it might appear there it's not

1063
00:46:30,470 --> 00:46:28,319

very easy to pose for pictures in

1064
00:46:32,630 --> 00:46:30,480
microgravity

1065
00:46:34,309 --> 00:46:32,640
especially when you're carrying a

1066
00:46:37,030 --> 00:46:34,319
multi-pound

1067
00:46:39,910 --> 00:46:37,040
object with you and so

1068
00:46:43,670 --> 00:46:41,829
it didn't actually go as easily as it

1069
00:46:44,710 --> 00:46:43,680
appeared in that other picture but we we

1070
00:46:47,270 --> 00:46:44,720
had fun

1071
00:46:48,790 --> 00:46:47,280
and working on the experiment whether

1072
00:46:50,470 --> 00:46:48,800
that be in front of it or from the

1073
00:46:53,109 --> 00:46:50,480
ceiling

1074
00:46:54,790 --> 00:46:53,119
and um i was not working this fast i

1075
00:46:56,550 --> 00:46:54,800
appreciate kamal mentioning that i

1076
00:46:58,790 --> 00:46:56,560
apparently did work quickly this is a

1077
00:47:00,150 --> 00:46:58,800
sped up video of some things and

1078
00:47:01,430 --> 00:47:00,160
actually i need to go back because i

1079
00:47:02,790 --> 00:47:01,440
missed the one thing i wanted to show

1080
00:47:04,390 --> 00:47:02,800
you so just going to narrate a little

1081
00:47:06,230 --> 00:47:04,400
bit like the real life side of what's

1082
00:47:07,589 --> 00:47:06,240
going on here so this

1083
00:47:09,750 --> 00:47:07,599
this thing over here is actually our

1084
00:47:12,390 --> 00:47:09,760
exercise bike and you'll see there's a

1085
00:47:14,870 --> 00:47:12,400
hand that pops on someone was actually

1086
00:47:17,109 --> 00:47:14,880
exercising on the exercise bike right

1087
00:47:18,550 --> 00:47:17,119
next to me while i was doing a lot of

1088
00:47:20,470 --> 00:47:18,560

this work

1089
00:47:22,790 --> 00:47:20,480
i put this one up i hope i'm not causing

1090
00:47:24,710 --> 00:47:22,800
anyone any consternation in the in the

1091
00:47:26,470 --> 00:47:24,720
cold adam lab team because i can only

1092
00:47:28,710 --> 00:47:26,480
imagine what was going through their

1093
00:47:30,630 --> 00:47:28,720
mind when they saw some stranger um with

1094
00:47:33,270 --> 00:47:30,640
their hands inside of their very very

1095
00:47:35,030 --> 00:47:33,280
delicate instrument and um and working

1096
00:47:37,750 --> 00:47:35,040
in the minutia but they did such an

1097
00:47:39,750 --> 00:47:37,760
awesome job of training me they actually

1098
00:47:41,750 --> 00:47:39,760
scheduled time for me to learn how to

1099
00:47:44,950 --> 00:47:41,760
use all of these new tools with lasers

1100
00:47:46,950 --> 00:47:44,960
and the fiber optics um there i am so

1101
00:47:48,630 --> 00:47:46,960
this you you notice i went off camera

1102
00:47:50,950 --> 00:47:48,640
for a second while i'm talking to jim

1103
00:47:52,390 --> 00:47:50,960
and that was the uh space equivalent of

1104
00:47:54,230 --> 00:47:52,400
being on mute

1105
00:47:57,030 --> 00:47:54,240
because i tried to talk to him with our

1106
00:47:59,270 --> 00:47:57,040
audio unit not turned on there so that

1107
00:48:03,829 --> 00:47:59,280
just shows you that that i started that

1108
00:48:07,589 --> 00:48:04,829
and

1109
00:48:09,030 --> 00:48:07,599
um i just did a little day in the life i

1110
00:48:12,069 --> 00:48:09,040
really enjoyed going back through these

1111
00:48:13,910 --> 00:48:12,079
videos to prepare for today

1112
00:48:15,270 --> 00:48:13,920
and i wanted to also thank you all i

1113
00:48:17,670 --> 00:48:15,280

don't know if you heard about this was

1114
00:48:20,069 --> 00:48:17,680
the first all-female replacement of a

1115
00:48:22,630 --> 00:48:20,079
science module on a cold atom lab that

1116
00:48:25,589 --> 00:48:22,640
was also done during my mission and

1117
00:48:27,030 --> 00:48:25,599
obviously just a joke but um there was

1118
00:48:28,549 --> 00:48:27,040
there was an opportunity that i got to

1119
00:48:30,710 --> 00:48:28,559
work with jessica on this so that's

1120
00:48:32,470 --> 00:48:30,720
always fun

1121
00:48:34,309 --> 00:48:32,480
but we don't only work on board the

1122
00:48:35,750 --> 00:48:34,319
space station yes we have some time off

1123
00:48:37,750 --> 00:48:35,760
one of my favorite things to do in my

1124
00:48:39,109 --> 00:48:37,760
time off was to be in the cupola window

1125
00:48:40,230 --> 00:48:39,119
looking down on earth and taking

1126
00:48:43,030 --> 00:48:40,240
pictures

1127
00:48:44,950 --> 00:48:43,040
and including one of

1128
00:48:46,630 --> 00:48:44,960
you all

1129
00:48:48,710 --> 00:48:46,640
oh the circle didn't show up but there

1130
00:48:51,190 --> 00:48:48,720
was a circle around you guys or did it

1131
00:48:53,750 --> 00:48:51,200
show up okay thank you um but my

1132
00:48:56,470 --> 00:48:53,760
favorite night photography i i obviously

1133
00:48:57,829 --> 00:48:56,480
really enjoy this and looking down on

1134
00:48:59,349 --> 00:48:57,839
those cold regions that have the

1135
00:49:02,710 --> 00:48:59,359
northern lights and southern lights from

1136
00:49:05,670 --> 00:49:02,720
up there was really special for me

1137
00:49:07,349 --> 00:49:05,680
this is my video this is just us having

1138
00:49:08,790 --> 00:49:07,359

a little bit of fun that's me and nick

1139
00:49:10,710 --> 00:49:08,800
hague and you can see drew morgan

1140
00:49:13,430 --> 00:49:10,720
actually exercising in the background

1141
00:49:15,750 --> 00:49:13,440
but this is in my mind what's happening

1142
00:49:17,190 --> 00:49:15,760
inside cold adam lab

1143
00:49:19,270 --> 00:49:17,200
there's a blob

1144
00:49:21,270 --> 00:49:19,280
and thanks to being in space we can

1145
00:49:24,309 --> 00:49:21,280
maintain that blob a little longer than

1146
00:49:26,630 --> 00:49:24,319
we can maintain blobs on earth and you

1147
00:49:28,870 --> 00:49:26,640
know there's like we talk about no

1148
00:49:32,069 --> 00:49:28,880
asymmetric interaction with boundary

1149
00:49:34,870 --> 00:49:32,079
conditions and a longer longer lifetime

1150
00:49:37,589 --> 00:49:34,880
so so i i wanted to offer that up as a

1151
00:49:40,230 --> 00:49:37,599
little explanation

1152
00:49:41,430 --> 00:49:40,240
of course no no recreational time is

1153
00:49:43,270 --> 00:49:41,440
complete without dinner with your

1154
00:49:45,589 --> 00:49:43,280
buddies and that was another fun way

1155
00:49:47,270 --> 00:49:45,599
that we we bonded as a crew

1156
00:49:50,549 --> 00:49:47,280
of course all good things must come to

1157
00:49:52,470 --> 00:49:50,559
an end and eventually after 328 days uh

1158
00:49:55,109 --> 00:49:52,480
the day that i did the upgrade on cal

1159
00:49:57,270 --> 00:49:55,119
was like day 320 believe it or not i

1160
00:49:58,390 --> 00:49:57,280
slipped it right in before i got to come

1161
00:49:59,589 --> 00:49:58,400
home

1162
00:50:04,630 --> 00:49:59,599
and

1163
00:50:07,270 --> 00:50:04,640

extracted from the spacecraft

1164
00:50:08,630 --> 00:50:07,280
and actually 24 hours later being back

1165
00:50:11,589 --> 00:50:08,640
in houston

1166
00:50:16,069 --> 00:50:11,599
this is me thinking i did it i worked on

1167
00:50:19,829 --> 00:50:18,230
and of course we are at a really

1168
00:50:21,270 --> 00:50:19,839
exciting time now what's next for

1169
00:50:23,190 --> 00:50:21,280
astronauts and this is where the

1170
00:50:24,790 --> 00:50:23,200
partnership between the human space

1171
00:50:26,950 --> 00:50:24,800
flight at johnson space center and what

1172
00:50:28,549 --> 00:50:26,960
you all do here at jpl is so important

1173
00:50:30,069 --> 00:50:28,559
because we are going back to the moon

1174
00:50:32,309 --> 00:50:30,079
we're going to be partnering the

1175
00:50:35,030 --> 00:50:32,319
robotics and the humans together

1176
00:50:37,030 --> 00:50:35,040
obviously can do more than than what any

1177
00:50:39,589 --> 00:50:37,040
of us can do alone and i think cold adam

1178
00:50:40,790 --> 00:50:39,599
labs collaboration showed that as well

1179
00:50:43,589 --> 00:50:40,800
as the future work that we're going to

1180
00:50:45,109 --> 00:50:43,599
do so we can't wait and at johnson space

1181
00:50:47,430 --> 00:50:45,119
center to keep working with you all as

1182
00:50:49,349 --> 00:50:47,440
you all explore other bodies and we're a

1183
00:50:56,630 --> 00:50:49,359
part of it

1184
00:51:01,829 --> 00:50:59,030
thank you christina yes i want to say

1185
00:51:04,230 --> 00:51:01,839
something yeah so the science module

1186
00:51:06,069 --> 00:51:04,240
that you replaced uh

1187
00:51:09,190 --> 00:51:06,079
we brought it back

1188
00:51:12,150 --> 00:51:09,200

to earth and he has found a home at the

1189
00:51:13,270 --> 00:51:12,160
smithsonian museum so it will be given

1190
00:51:15,109 --> 00:51:13,280
to them

1191
00:51:16,950 --> 00:51:15,119
soon so we just want to make this

1192
00:51:28,069 --> 00:51:16,960
announcement and let you know so thank

1193
00:51:31,990 --> 00:51:29,670
okay thank you

1194
00:51:34,390 --> 00:51:32,000
i'm jason williams i am the project

1195
00:51:37,349 --> 00:51:34,400
scientist for the cold adam lab and

1196
00:51:39,589 --> 00:51:37,359
i have the distinction to introduce uh

1197
00:51:41,990 --> 00:51:39,599
professor nobel laureate eric cornell in

1198
00:51:43,349 --> 00:51:42,000
just a few minutes but um i wanted to

1199
00:51:47,030 --> 00:51:43,359
take a minute to talk to you about the

1200
00:51:49,349 --> 00:51:47,040
science that that we and the the

1201
00:51:52,630 --> 00:51:49,359
distinguished and very helpful uh pi

1202
00:51:54,390 --> 00:51:52,640
team have been doing and

1203
00:51:56,470 --> 00:51:54,400
so

1204
00:51:58,790 --> 00:51:56,480
cold adam lab has been operating for

1205
00:52:00,870 --> 00:51:58,800
four years and it has been an exciting

1206
00:52:02,710 --> 00:52:00,880
four years i'll tell you that i see

1207
00:52:05,030 --> 00:52:02,720
i see a lot of

1208
00:52:07,430 --> 00:52:05,040
some of the members of the cold adam lab

1209
00:52:10,150 --> 00:52:07,440
team that are here it's it's been

1210
00:52:12,790 --> 00:52:10,160
uh a uh

1211
00:52:15,349 --> 00:52:12,800
a big effort a fulfilling effort for

1212
00:52:17,430 --> 00:52:15,359
many of us and uh not only scientists

1213
00:52:20,069 --> 00:52:17,440

engineers

1214
00:52:22,470 --> 00:52:20,079
team students it's it's been i've never

1215
00:52:23,430 --> 00:52:22,480
worked with a greater group of people um

1216
00:52:26,230 --> 00:52:23,440
and

1217
00:52:27,990 --> 00:52:26,240
uh astronaut uh christina koch was

1218
00:52:30,630 --> 00:52:28,000
talking about um

1219
00:52:32,790 --> 00:52:30,640
doing some of the work that on cold adam

1220
00:52:34,390 --> 00:52:32,800
lab replacing it we got the chance to

1221
00:52:36,390 --> 00:52:34,400
watch this from the ground it was

1222
00:52:37,829 --> 00:52:36,400
exciting also one of the scariest

1223
00:52:40,390 --> 00:52:37,839
moments of my life

1224
00:52:42,069 --> 00:52:40,400
but she did an amazing job because as

1225
00:52:44,630 --> 00:52:42,079
you'll see we've gotten some some really

1226
00:52:46,710 --> 00:52:44,640
great science out so

1227
00:52:48,069 --> 00:52:46,720
as kamal had mentioned we've operated

1228
00:52:51,190 --> 00:52:48,079
for four years

1229
00:52:52,870 --> 00:52:51,200
we also have collected uh

1230
00:52:55,349 --> 00:52:52,880
tens of thousands of experimental runs

1231
00:52:57,349 --> 00:52:55,359
for the the pi teams and so this is

1232
00:52:58,950 --> 00:52:57,359
absolutely the most bizarre einstein

1233
00:53:01,190 --> 00:52:58,960
condensates that have been produced in

1234
00:53:04,069 --> 00:53:01,200
earth this has actually been

1235
00:53:06,549 --> 00:53:04,079
demonstrated as uh the first multi-user

1236
00:53:09,109 --> 00:53:06,559
facility for quantum gas research on

1237
00:53:11,670 --> 00:53:09,119
in space and it has really fulfilled its

1238
00:53:15,030 --> 00:53:11,680

promise going above and beyond uh the

1239
00:53:17,190 --> 00:53:15,040
initial um mission lifetime

1240
00:53:19,270 --> 00:53:17,200
we chew chief bose-einstein condensates

1241
00:53:21,990 --> 00:53:19,280
in space in fact we produce them every

1242
00:53:23,750 --> 00:53:22,000
day as part of our startup and

1243
00:53:25,910 --> 00:53:23,760
and

1244
00:53:28,390 --> 00:53:25,920
we can now

1245
00:53:30,710 --> 00:53:28,400
not only do experiments with rubidium so

1246
00:53:33,190 --> 00:53:30,720
a single atomic species but we can

1247
00:53:37,670 --> 00:53:35,109
dual atomic species both einstein

1248
00:53:39,030 --> 00:53:37,680
condensates rubidium and potassium these

1249
00:53:41,270 --> 00:53:39,040
are different very different atomic

1250
00:53:43,109 --> 00:53:41,280
species they have different masses

1251
00:53:45,670 --> 00:53:43,119
completely different properties and we

1252
00:53:47,589 --> 00:53:45,680
can also produce those at the same time

1253
00:53:49,829 --> 00:53:47,599
and manipulate them in space allow them

1254
00:53:52,309 --> 00:53:49,839
to interact and

1255
00:53:54,230 --> 00:53:52,319
flushes out another very large body of

1256
00:53:56,630 --> 00:53:54,240
physics that has been opened up for the

1257
00:53:59,510 --> 00:53:56,640
first time in space studying interacting

1258
00:54:02,870 --> 00:53:59,520
now ultra cold quantum gases

1259
00:54:05,430 --> 00:54:02,880
we've also as part of the commissioning

1260
00:54:08,390 --> 00:54:05,440
seen atoms just floating in space and

1261
00:54:09,270 --> 00:54:08,400
free fall for seconds time scales which

1262
00:54:14,390 --> 00:54:09,280
is

1263
00:54:16,549 --> 00:54:14,400

um

1264
00:54:18,710 --> 00:54:16,559
as also uh kamal had mentioned we've

1265
00:54:20,230 --> 00:54:18,720
achieved unprecedented cooling to sub

1266
00:54:22,870 --> 00:54:20,240
sub nano kelvin temperatures even down

1267
00:54:25,829 --> 00:54:22,880
to the 52 pico kelvin regime so

1268
00:54:28,630 --> 00:54:25,839
uh this this picture i really

1269
00:54:30,630 --> 00:54:28,640
enjoy of uh astronaut

1270
00:54:33,349 --> 00:54:30,640
finding a bose einstein condensate in

1271
00:54:35,109 --> 00:54:33,359
space and observing its properties uh in

1272
00:54:36,870 --> 00:54:35,119
many ways that's that's what we're doing

1273
00:54:39,349 --> 00:54:36,880
though we're releasing these atoms in

1274
00:54:41,190 --> 00:54:39,359
space we actually take pictures of them

1275
00:54:43,349 --> 00:54:41,200
as part of our

1276
00:54:47,030 --> 00:54:43,359
our data return and we're seeing what

1277
00:54:48,230 --> 00:54:47,040
they do we see their unique properties

1278
00:54:49,510 --> 00:54:48,240
so

1279
00:54:51,589 --> 00:54:49,520
um

1280
00:54:52,950 --> 00:54:51,599
okay so uh

1281
00:54:54,150 --> 00:54:52,960
i wanted to take a few minutes to talk

1282
00:54:55,910 --> 00:54:54,160
about the pi teams because they're

1283
00:54:58,549 --> 00:54:55,920
really the heart of what we're doing in

1284
00:55:00,789 --> 00:54:58,559
cold adam lab there were five

1285
00:55:03,910 --> 00:55:00,799
flight pi teams that were chosen for the

1286
00:55:05,589 --> 00:55:03,920
initial cal nra and these are really

1287
00:55:07,430 --> 00:55:05,599
pathfinders no one's ever done

1288
00:55:09,109 --> 00:55:07,440

experiments like these five pi's have

1289
00:55:10,470 --> 00:55:09,119
done before

1290
00:55:13,670 --> 00:55:10,480
and so

1291
00:55:15,430 --> 00:55:13,680
for example uh nathan lemblet

1292
00:55:19,589 --> 00:55:15,440
has been doing some experiments

1293
00:55:21,990 --> 00:55:19,599
observing ultracold gases in bubble

1294
00:55:24,150 --> 00:55:22,000
geometries in space and so how does the

1295
00:55:25,510 --> 00:55:24,160
quantum gas with wave-like nature

1296
00:55:28,230 --> 00:55:25,520
perform when it's in this unique

1297
00:55:30,309 --> 00:55:28,240
topology of a bubble or a shell these

1298
00:55:32,549 --> 00:55:30,319
are experiments that are beginning and

1299
00:55:33,750 --> 00:55:32,559
have been progressing well for nathan

1300
00:55:36,870 --> 00:55:33,760
lundblad

1301
00:55:39,349 --> 00:55:36,880
the team by nick bigelow

1302
00:55:41,030 --> 00:55:39,359
he leads a consortium that includes

1303
00:55:42,950 --> 00:55:41,040
nobel laureates wolfgang ketterly and

1304
00:55:47,190 --> 00:55:42,960
bill phillips and his team is really

1305
00:55:49,109 --> 00:55:47,200
exploring okay i have two atomic species

1306
00:55:50,950 --> 00:55:49,119
if i perform adam interferometry on it

1307
00:55:53,109 --> 00:55:50,960
which i will explain a little bit more

1308
00:55:55,829 --> 00:55:53,119
in a few minutes this can be a very

1309
00:55:58,150 --> 00:55:55,839
precise uh sensor for gravity so how can

1310
00:56:00,870 --> 00:55:58,160
we take cal where it is mature the

1311
00:56:03,510 --> 00:56:00,880
technology so that someday we can

1312
00:56:05,589 --> 00:56:03,520
perform dual species adam interferometry

1313
00:56:08,230 --> 00:56:05,599

and try to test some of einstein's

1314
00:56:10,630 --> 00:56:08,240
theories such as the universality of

1315
00:56:12,870 --> 00:56:10,640
free fall or do these quantum objects

1316
00:56:14,710 --> 00:56:12,880
fall the same in gravity we know they do

1317
00:56:18,230 --> 00:56:14,720
but to what level do they really fall at

1318
00:56:21,190 --> 00:56:18,240
the same rates in gravity and

1319
00:56:23,750 --> 00:56:21,200
the group of um

1320
00:56:26,549 --> 00:56:23,760
of eric cornell uh you'll hear a little

1321
00:56:28,230 --> 00:56:26,559
bit of his talk uh of what he's doing

1322
00:56:30,390 --> 00:56:28,240
but his group is

1323
00:56:32,549 --> 00:56:30,400
along with peter ingalls is studying the

1324
00:56:35,270 --> 00:56:32,559
quantum three body problem which is a

1325
00:56:37,030 --> 00:56:35,280
very difficult problem to study but it

1326
00:56:39,109 --> 00:56:37,040
has universal properties that can be

1327
00:56:40,789 --> 00:56:39,119
extended to other systems

1328
00:56:42,069 --> 00:56:40,799
sort of analogous to feynman's quantum

1329
00:56:44,549 --> 00:56:42,079
simulator

1330
00:56:46,470 --> 00:56:44,559
we can take atoms as quantum systems we

1331
00:56:47,750 --> 00:56:46,480
can simulate their properties now how

1332
00:56:50,390 --> 00:56:47,760
does that extend to the rest of the

1333
00:56:51,829 --> 00:56:50,400
quantum world perhaps like nuclei and

1334
00:56:55,190 --> 00:56:51,839
molecules and other things that are much

1335
00:56:56,870 --> 00:56:55,200
much more difficult to study

1336
00:57:00,630 --> 00:56:56,880
cass sackett's group is studying

1337
00:57:03,349 --> 00:57:00,640
adiabatic cooling in space a lot of his

1338
00:57:04,549 --> 00:57:03,359

initial efforts are how cold can we make

1339
00:57:07,109 --> 00:57:04,559
things if you

1340
00:57:10,470 --> 00:57:07,119
have space have a uniform environment

1341
00:57:12,390 --> 00:57:10,480
and you relax the confinement and

1342
00:57:14,069 --> 00:57:12,400
so-called adiabatic cooling but make

1343
00:57:15,349 --> 00:57:14,079
extremely weak traps your atoms are

1344
00:57:17,349 --> 00:57:15,359
going to get really cold and really

1345
00:57:19,270 --> 00:57:17,359
trying to push the limits of how

1346
00:57:22,230 --> 00:57:19,280
how well we can

1347
00:57:24,870 --> 00:57:22,240
prepare ultracold gases in space

1348
00:57:27,190 --> 00:57:24,880
and then my team is studying um

1349
00:57:29,829 --> 00:57:27,200
fetchbox molecules these unique type of

1350
00:57:31,829 --> 00:57:29,839
molecules with quantum gases uh it's

1351
00:57:34,230 --> 00:57:31,839
it's sort of a form of quantum chemistry

1352
00:57:36,230 --> 00:57:34,240
how can we form these molecules and how

1353
00:57:37,349 --> 00:57:36,240
can these be used as a very precise

1354
00:57:39,510 --> 00:57:37,359
source for

1355
00:57:41,109 --> 00:57:39,520
uh precision measurement in the in the

1356
00:57:44,630 --> 00:57:41,119
future

1357
00:57:46,789 --> 00:57:44,640
and so this is uh these are um initial

1358
00:57:49,109 --> 00:57:46,799
experiments uh that

1359
00:57:50,789 --> 00:57:49,119
have popped up these are all our space

1360
00:57:53,109 --> 00:57:50,799
enabled um

1361
00:57:55,510 --> 00:57:53,119
and we've been getting some some very

1362
00:57:57,990 --> 00:57:55,520
impressive results

1363
00:57:59,349 --> 00:57:58,000

to zoom in a bit more since the

1364
00:58:02,230 --> 00:57:59,359
upgrade

1365
00:58:03,349 --> 00:58:02,240
by astronaut coke we've this brought to

1366
00:58:07,109 --> 00:58:03,359
us the capability for atom

1367
00:58:09,430 --> 00:58:07,119
interferometry and adam interferometry

1368
00:58:11,789 --> 00:58:09,440
says okay we know that atoms are waves

1369
00:58:14,710 --> 00:58:11,799
we've known that since the

1370
00:58:16,069 --> 00:58:14,720
1920s it's one of the basics of quantum

1371
00:58:18,069 --> 00:58:16,079
mechanics

1372
00:58:20,630 --> 00:58:18,079
using some more recent technologies that

1373
00:58:23,270 --> 00:58:20,640
have been developed to use laser pulses

1374
00:58:25,270 --> 00:58:23,280
you can use a laser pulse and split two

1375
00:58:27,349 --> 00:58:25,280
wave atom waves apart

1376
00:58:28,470 --> 00:58:27,359
and allow it to recombine and interfere

1377
00:58:30,549 --> 00:58:28,480
with itself

1378
00:58:32,950 --> 00:58:30,559
and you make an atom interferometer out

1379
00:58:34,630 --> 00:58:32,960
of matter waves

1380
00:58:37,510 --> 00:58:34,640
this uh

1381
00:58:40,870 --> 00:58:37,520
this is a technology that is uh

1382
00:58:42,789 --> 00:58:40,880
developed on birth on earth it uh

1383
00:58:45,750 --> 00:58:42,799
has a lot of promise and space because

1384
00:58:47,589 --> 00:58:45,760
in space you uh don't need to drop your

1385
00:58:49,109 --> 00:58:47,599
atoms and allow them to drop a long

1386
00:58:52,230 --> 00:58:49,119
distance you release them and your atoms

1387
00:58:55,990 --> 00:58:52,240
float in free fall and we have

1388
00:58:58,549 --> 00:58:56,000

some very uh cutting edge result results

1389
00:59:01,190 --> 00:58:58,559
we've demonstrated for the first time

1390
00:59:03,430 --> 00:59:01,200
a dual species atom interferometer where

1391
00:59:05,270 --> 00:59:03,440
single laser pulse

1392
00:59:07,670 --> 00:59:05,280
creates two atom interferometers and we

1393
00:59:10,069 --> 00:59:07,680
see how gravity at a very low level acts

1394
00:59:12,309 --> 00:59:10,079
on potassium and rubidium and this is a

1395
00:59:13,829 --> 00:59:12,319
basis for for experiments that are going

1396
00:59:16,230 --> 00:59:13,839
on but first time that this has been

1397
00:59:18,789 --> 00:59:16,240
demonstrated in space and this as i

1398
00:59:21,030 --> 00:59:18,799
mentioned will form the basis of

1399
00:59:22,390 --> 00:59:21,040
eventually maturing the technology to

1400
00:59:24,230 --> 00:59:22,400
look for

1401
00:59:25,910 --> 00:59:24,240
violations of the equivalence principle

1402
00:59:27,510 --> 00:59:25,920
and this is one of the great tools that

1403
00:59:28,630 --> 00:59:27,520
has promised for searching for new

1404
00:59:30,870 --> 00:59:28,640
physics

1405
00:59:32,870 --> 00:59:30,880
in the future

1406
00:59:35,510 --> 00:59:32,880
so with that

1407
00:59:37,829 --> 00:59:35,520
i would like to introduce

1408
00:59:40,789 --> 00:59:37,839
a professor and nobel laureate eric

1409
00:59:40,799 --> 00:59:45,510
thank you

1410
00:59:52,789 --> 00:59:49,349
so eric is a um

1411
00:59:54,789 --> 00:59:52,799
a fellow of nistangila uh a adjoint

1412
00:59:56,630 --> 00:59:54,799
professor at the university of calr

1413
00:59:58,470 --> 00:59:56,640

colorado in boulder

1414
01:00:00,630 --> 00:59:58,480
he has a very long resume i had a hard

1415
01:00:02,870 --> 01:00:00,640
time distilling it down but

1416
01:00:04,309 --> 01:00:02,880
his current research includes uh

1417
01:00:06,309 --> 01:00:04,319
searches for the electric dip a

1418
01:00:08,470 --> 01:00:06,319
permanent electric dipole moment some

1419
01:00:11,670 --> 01:00:08,480
studies of strongly interacting

1420
01:00:15,589 --> 01:00:11,680
gases and the fu body problem he's a

1421
01:00:17,990 --> 01:00:15,599
pete one of the first pis on cal and

1422
01:00:19,589 --> 01:00:18,000
he also has a a very distinguished

1423
01:00:22,309 --> 01:00:19,599
awards record

1424
01:00:23,349 --> 01:00:22,319
received the presidential early career

1425
01:00:25,030 --> 01:00:23,359
award

1426
01:00:26,470 --> 01:00:25,040
robbie prize

1427
01:00:29,030 --> 01:00:26,480
member of the national academies of

1428
01:00:32,150 --> 01:00:29,040
science and in 2001 he received the

1429
01:00:34,309 --> 01:00:32,160
nobel prize along with wolfgang ketterly

1430
01:00:35,829 --> 01:00:34,319
and carl weinman for

1431
01:00:39,270 --> 01:00:35,839
first demonstration of bose einstein

1432
01:00:41,109 --> 01:00:39,280
condensation in a dilute gas so

1433
01:00:44,390 --> 01:00:41,119
we wanted to

1434
01:00:47,349 --> 01:00:44,400
present this award to him

1435
01:00:51,270 --> 01:00:47,359
and so i will again let allow

1436
01:01:07,750 --> 01:00:51,280
uh kr2 to present it but this is for in

1437
01:01:13,510 --> 01:01:11,349
recognition of his leadership in

1438
01:01:21,510 --> 01:01:13,520

support of the advance of cold adam

1439
01:01:25,270 --> 01:01:23,270
and thank you jason it's always really a

1440
01:01:27,270 --> 01:01:25,280
lot of fun for me to come to jpl this is

1441
01:01:28,870 --> 01:01:27,280
the fourth anniversary of cal and space

1442
01:01:30,950 --> 01:01:28,880
but i've been involved one way or

1443
01:01:32,630 --> 01:01:30,960
another in the program for eight years

1444
01:01:33,910 --> 01:01:32,640
going on a decade and it's been so

1445
01:01:36,150 --> 01:01:33,920
exciting for me

1446
01:01:38,390 --> 01:01:36,160
uh if i had on if i had only a single

1447
01:01:42,230 --> 01:01:38,400
gripe it would be that somehow at cal

1448
01:01:44,150 --> 01:01:42,240
events i often end up speaking after uh

1449
01:01:45,829 --> 01:01:44,160
jason and christina and i always feel a

1450
01:01:48,630 --> 01:01:45,839
little bit not quite as polished but i'm

1451
01:01:53,510 --> 01:01:50,470
i'm here to talk about

1452
01:01:54,549 --> 01:01:53,520
people have alluded before to quantum in

1453
01:01:57,029 --> 01:01:54,559
space

1454
01:01:59,349 --> 01:01:57,039
and uh that's the topic of my in my uh

1455
01:02:01,029 --> 01:01:59,359
talk today

1456
01:02:03,510 --> 01:02:01,039
before we can talk about quantum and

1457
01:02:06,630 --> 01:02:03,520
space i want to talk about uh ultra cold

1458
01:02:07,750 --> 01:02:06,640
ultra cold in space

1459
01:02:09,990 --> 01:02:07,760
and uh

1460
01:02:11,990 --> 01:02:10,000
vi and and sort of tie that into a word

1461
01:02:14,150 --> 01:02:12,000
we've already heard before which is bose

1462
01:02:15,670 --> 01:02:14,160
einstein conversation and space space

1463
01:02:17,910 --> 01:02:15,680

space

1464
01:02:19,750 --> 01:02:17,920
i'll probably forget uh

1465
01:02:21,589 --> 01:02:19,760
you know when giving a sort of popular

1466
01:02:23,270 --> 01:02:21,599
level lecture when tries not to use

1467
01:02:25,990 --> 01:02:23,280
acronyms i'll probably forget and call

1468
01:02:28,230 --> 01:02:26,000
it bec but you're not really working at

1469
01:02:30,630 --> 01:02:28,240
nasa or jpl if you don't throw a lot of

1470
01:02:32,789 --> 01:02:30,640
around a lot of tlas and so i've got

1471
01:02:34,870 --> 01:02:32,799
into the habit myself bec bose einstein

1472
01:02:36,789 --> 01:02:34,880
condensation so i'm going to start with

1473
01:02:39,510 --> 01:02:36,799
the cold and just to put things in

1474
01:02:42,230 --> 01:02:39,520
context uh scientists engineers we

1475
01:02:42,950 --> 01:02:42,240
measure temperatures in absolute units

1476
01:02:51,589 --> 01:02:42,960
so

1477
01:02:53,349 --> 01:02:51,599
what we would call minus 460 fahrenheit

1478
01:02:55,270 --> 01:02:53,359
is what we would call absolute zero zero

1479
01:02:56,789 --> 01:02:55,280
degrees kelvin it can't ever get to zero

1480
01:02:59,190 --> 01:02:56,799
degrees kelvin but as we'll see you can

1481
01:03:00,630 --> 01:02:59,200
get awfully close

1482
01:03:02,390 --> 01:03:00,640
an important line which you can maybe

1483
01:03:04,630 --> 01:03:02,400
just barely see in the auditorium here

1484
01:03:06,230 --> 01:03:04,640
is just barely above that purple line is

1485
01:03:07,349 --> 01:03:06,240
the temperature of deep space three

1486
01:03:09,109 --> 01:03:07,359
kelvin

1487
01:03:12,630 --> 01:03:09,119
which is uh people have already alluded

1488
01:03:14,309 --> 01:03:12,640

to cold but yeah not really

1489
01:03:16,069 --> 01:03:14,319
we get a whole lot colder in fact we're

1490
01:03:18,470 --> 01:03:16,079
gonna the next slide we're gonna expand

1491
01:03:21,029 --> 01:03:18,480
out between that zero and three

1492
01:03:22,870 --> 01:03:21,039
and uh draw the analogy uh the three to

1493
01:03:25,510 --> 01:03:22,880
three degree temperature of deep space

1494
01:03:26,789 --> 01:03:25,520
is to mount everest as uh say the

1495
01:03:29,029 --> 01:03:26,799
thickness of a

1496
01:03:30,710 --> 01:03:29,039
100 nano kelvin the typical temperature

1497
01:03:32,789 --> 01:03:30,720
of both einstein condensation is to the

1498
01:03:35,750 --> 01:03:32,799
thickness of a pencil lead say a

1499
01:03:37,750 --> 01:03:35,760
millimeter so we're going down uh

1500
01:03:39,430 --> 01:03:37,760
you know whatever this works out to here

1501
01:03:41,349 --> 01:03:39,440
seven eight orders of magnitude down in

1502
01:03:43,589 --> 01:03:41,359
temperature from what already people

1503
01:03:45,670 --> 01:03:43,599
usually think of as a very cold place

1504
01:03:47,990 --> 01:03:45,680
why so cold what's the relevance in cold

1505
01:03:49,510 --> 01:03:48,000
and how does that connect us back to

1506
01:03:51,510 --> 01:03:49,520
the quantum mechanics and i will say

1507
01:03:53,510 --> 01:03:51,520
it's a little bit of a spoiler alert

1508
01:03:55,349 --> 01:03:53,520
this 100 nano kelvin which i'm making

1509
01:03:58,069 --> 01:03:55,359
such a big deal 100 billionths of a

1510
01:04:01,190 --> 01:03:58,079
degree above absolute zero cal gets a

1511
01:04:03,510 --> 01:04:01,200
whole lot colder than that

1512
01:04:05,829 --> 01:04:03,520
um i i don't have time

1513
01:04:07,349 --> 01:04:05,839

to talk about how we get so very very

1514
01:04:10,309 --> 01:04:07,359
cold people have already alluded to

1515
01:04:12,950 --> 01:04:10,319
lasers and indeed uh we use the the

1516
01:04:15,430 --> 01:04:12,960
pressure of lasers of photons bouncing

1517
01:04:17,670 --> 01:04:15,440
off of atoms think of throwing ping-pong

1518
01:04:19,029 --> 01:04:17,680
balls at at bowling balls and if you

1519
01:04:20,710 --> 01:04:19,039
throw enough ping-pong balls at bowling

1520
01:04:22,710 --> 01:04:20,720
balls you could slow down a bowling ball

1521
01:04:24,870 --> 01:04:22,720
if it happened to be rolling towards you

1522
01:04:26,630 --> 01:04:24,880
being going slower means being colder

1523
01:04:28,069 --> 01:04:26,640
that's laser cooling

1524
01:04:29,750 --> 01:04:28,079
and then

1525
01:04:32,230 --> 01:04:29,760
laser cooling is part of it and magnetic

1526
01:04:34,630 --> 01:04:32,240
trapping is part of it too both on on

1527
01:04:36,470 --> 01:04:34,640
earth and in space we have a strong

1528
01:04:38,470 --> 01:04:36,480
magnetic fields that keep the atoms

1529
01:04:40,390 --> 01:04:38,480
together in a little blob and we let the

1530
01:04:42,470 --> 01:04:40,400
hottest atoms fall out of the edges much

1531
01:04:44,710 --> 01:04:42,480
like a a cup of hot coffee lets the

1532
01:04:47,029 --> 01:04:44,720
steam flow out uh get the

1533
01:04:49,109 --> 01:04:47,039
cup of hot coffee you see the steam

1534
01:04:50,950 --> 01:04:49,119
coming out that represents the hottest

1535
01:04:52,549 --> 01:04:50,960
of the coffee molecules making a break

1536
01:04:54,470 --> 01:04:52,559
for it and taking away with them more

1537
01:04:56,309 --> 01:04:54,480
than their fair share of energy cooling

1538
01:04:58,230 --> 01:04:56,319

the remaining coffee off evaporative

1539
01:04:59,589 --> 01:04:58,240
cooling and a magnetic trap these two

1540
01:05:01,510 --> 01:04:59,599
techniques allow us to get the bose

1541
01:05:03,910 --> 01:05:01,520
einstein condensation here's some

1542
01:05:05,190 --> 01:05:03,920
picture from really a long long time ago

1543
01:05:07,670 --> 01:05:05,200
early pictures of bose einstein

1544
01:05:10,150 --> 01:05:07,680
condensation you'll see these

1545
01:05:11,829 --> 01:05:10,160
false color images multiple times you

1546
01:05:14,390 --> 01:05:11,839
already have seen them these just

1547
01:05:16,069 --> 01:05:14,400
represent density plots basically

1548
01:05:18,230 --> 01:05:16,079
you turn off the magnetic trap you let

1549
01:05:20,309 --> 01:05:18,240
the atoms fly apart for a little while

1550
01:05:22,950 --> 01:05:20,319
and if they're going relatively fast as

1551
01:05:24,470 --> 01:05:22,960
they would be at 400 nano kelvin they

1552
01:05:26,069 --> 01:05:24,480
spread out in both directions and when

1553
01:05:28,789 --> 01:05:26,079
we take a picture we turn these shadow

1554
01:05:30,789 --> 01:05:28,799
images into into these mountain like

1555
01:05:33,109 --> 01:05:30,799
pictures if they're quite a bit colder

1556
01:05:36,069 --> 01:05:33,119
say 50 nano kelvin then we see this

1557
01:05:37,910 --> 01:05:36,079
single shark-like shark fin dorsal fin

1558
01:05:40,789 --> 01:05:37,920
which is the bose einstein condensate

1559
01:05:42,390 --> 01:05:40,799
it's a single wave uh representing all

1560
01:05:43,990 --> 01:05:42,400
the atoms participating in a bose

1561
01:05:45,829 --> 01:05:44,000
einstein condensation here we're

1562
01:05:47,510 --> 01:05:45,839
somewhere in between imagine that you've

1563
01:05:48,950 --> 01:05:47,520

you your ice tray is only a little bit

1564
01:05:50,710 --> 01:05:48,960
frozen you've got some ice and some

1565
01:05:54,150 --> 01:05:50,720
water some condensate and some regular

1566
01:05:58,630 --> 01:05:55,589
this is the group that did this low

1567
01:06:01,029 --> 01:05:58,640
these uh 30 some years ago

1568
01:06:02,150 --> 01:06:01,039
these people all went to stockholm with

1569
01:06:04,630 --> 01:06:02,160
us

1570
01:06:06,789 --> 01:06:04,640
for the nobel celebrations

1571
01:06:09,029 --> 01:06:06,799
uh and uh i mentioned particularly

1572
01:06:11,109 --> 01:06:09,039
debbie jin who was one of the very first

1573
01:06:14,309 --> 01:06:11,119
uh cal pis and unfortunately is no

1574
01:06:16,710 --> 01:06:14,319
longer with us died tragically young

1575
01:06:19,109 --> 01:06:16,720
uh what is this connection between very

1576
01:06:21,349 --> 01:06:19,119
cold and between quantum

1577
01:06:22,950 --> 01:06:21,359
and what is quantum and again begin with

1578
01:06:24,390 --> 01:06:22,960
uh some of you it's been a little while

1579
01:06:25,750 --> 01:06:24,400
since you took your first course in

1580
01:06:28,230 --> 01:06:25,760
quantum mechanics and so i'll just

1581
01:06:29,750 --> 01:06:28,240
review it here in about a minute um

1582
01:06:31,750 --> 01:06:29,760
atoms like everything else you can think

1583
01:06:33,829 --> 01:06:31,760
of them as two ways either the classical

1584
01:06:35,029 --> 01:06:33,839
way like like pool balls you know

1585
01:06:36,789 --> 01:06:35,039
bouncing off each other and maybe

1586
01:06:38,390 --> 01:06:36,799
falling into a pocket or like little

1587
01:06:41,430 --> 01:06:38,400
quantum waves

1588
01:06:43,190 --> 01:06:41,440

as things get colder they get wavier

1589
01:06:45,670 --> 01:06:43,200
what is that about why is making things

1590
01:06:47,270 --> 01:06:45,680
get colder make them wavier and really

1591
01:06:48,870 --> 01:06:47,280
it comes back to

1592
01:06:49,990 --> 01:06:48,880
if you don't know anything about quantum

1593
01:06:51,670 --> 01:06:50,000
mechanics but you've just read a

1594
01:06:52,870 --> 01:06:51,680
scientific american article you might

1595
01:06:54,710 --> 01:06:52,880
have heard of the

1596
01:06:56,390 --> 01:06:54,720
heisenberg's uncertainty principle you

1597
01:06:59,270 --> 01:06:56,400
can't simultaneously know where

1598
01:07:01,990 --> 01:06:59,280
something is and how fast it's going

1599
01:07:04,230 --> 01:07:02,000
well as you get colder and colder

1600
01:07:05,990 --> 01:07:04,240
you know how fast it's going because

1601
01:07:07,589 --> 01:07:06,000
colder and colder corresponds to moving

1602
01:07:08,470 --> 01:07:07,599
slower and slower so you can say on

1603
01:07:10,390 --> 01:07:08,480
average

1604
01:07:11,510 --> 01:07:10,400
the atoms are not moving at all and i

1605
01:07:13,270 --> 01:07:11,520
can say that with more and more

1606
01:07:15,349 --> 01:07:13,280
precision as i make the atoms colder and

1607
01:07:18,069 --> 01:07:15,359
colder their velocity is closer and

1608
01:07:20,710 --> 01:07:18,079
closer to zero heisenberg says

1609
01:07:22,069 --> 01:07:20,720
sorry if you know that very well how

1610
01:07:23,349 --> 01:07:22,079
fast something is going you can't know

1611
01:07:25,349 --> 01:07:23,359
where it is very well and so these

1612
01:07:27,109 --> 01:07:25,359
things look more and more like fuzzy

1613
01:07:29,270 --> 01:07:27,119

balls it's basically a

1614
01:07:31,670 --> 01:07:29,280
or a wave like object and it's a result

1615
01:07:33,589 --> 01:07:31,680
of of the uncertainty principle and if

1616
01:07:35,109 --> 01:07:33,599
you get really really cold then waviness

1617
01:07:37,349 --> 01:07:35,119
triumphs and you get bose einstein

1618
01:07:39,029 --> 01:07:37,359
condensation here in southern

1619
01:07:45,670 --> 01:07:39,039
california we would call it the ultimate

1620
01:07:50,069 --> 01:07:47,270
how are they like waves a beautiful

1621
01:07:53,190 --> 01:07:50,079
experiment done by another cal pi both

1622
01:07:54,630 --> 01:07:53,200
gone ketterly he took and it and it

1623
01:07:56,150 --> 01:07:54,640
you know it

1624
01:07:57,430 --> 01:07:56,160
pains me to say this because for many

1625
01:07:58,950 --> 01:07:57,440
years he and i were like arch

1626
01:08:01,029 --> 01:07:58,960
competitors but these days were kind of

1627
01:08:03,190 --> 01:08:01,039
pals and he did he did this beautiful

1628
01:08:04,549 --> 01:08:03,200
experiment and he took two condensates

1629
01:08:06,150 --> 01:08:04,559
and sort of two separate little magnetic

1630
01:08:08,710 --> 01:08:06,160
wells he let them overflow with each

1631
01:08:10,789 --> 01:08:08,720
other and when they overflowed you he

1632
01:08:12,549 --> 01:08:10,799
saw these stripes basically these

1633
01:08:14,710 --> 01:08:12,559
stripes are destructive interference

1634
01:08:16,630 --> 01:08:14,720
between atoms we think of waves like you

1635
01:08:18,070 --> 01:08:16,640
see ocean waves patterns of ocean waves

1636
01:08:19,349 --> 01:08:18,080
they can interfere constructively or

1637
01:08:20,950 --> 01:08:19,359
destructively

1638
01:08:22,789 --> 01:08:20,960

uh true for light you know you can get

1639
01:08:23,990 --> 01:08:22,799
laser wave lasers interfering with each

1640
01:08:24,950 --> 01:08:24,000
other and you get these interference

1641
01:08:26,870 --> 01:08:24,960
fringes

1642
01:08:28,789 --> 01:08:26,880
i find it still strange to imagine you

1643
01:08:30,070 --> 01:08:28,799
can take atoms plus atoms add them

1644
01:08:31,749 --> 01:08:30,080
together and get these sort of white

1645
01:08:34,550 --> 01:08:31,759
stripes which correspond to like no

1646
01:08:36,309 --> 01:08:34,560
atoms basically one set of atoms cancels

1647
01:08:38,709 --> 01:08:36,319
out the other atoms and this is

1648
01:08:40,390 --> 01:08:38,719
interference a common thing and things

1649
01:08:41,990 --> 01:08:40,400
which are waves and now we can see very

1650
01:08:44,950 --> 01:08:42,000
directly in these pictures that atoms

1651
01:08:47,030 --> 01:08:44,960
are waves these these so-called fringes

1652
01:08:49,110 --> 01:08:47,040
these interference patterns are

1653
01:08:51,269 --> 01:08:49,120
extremely sensitive

1654
01:08:53,910 --> 01:08:51,279
and they are sensitive to things like

1655
01:08:56,149 --> 01:08:53,920
acceleration and exotic new physics

1656
01:08:58,470 --> 01:08:56,159
of there's a proposal out to use things

1657
01:09:00,309 --> 01:08:58,480
like this to detect exotic new physics

1658
01:09:02,309 --> 01:09:00,319
including the gravity coming from things

1659
01:09:04,630 --> 01:09:02,319
you can't otherwise see

1660
01:09:06,709 --> 01:09:04,640
where do we hear about that dark matter

1661
01:09:08,229 --> 01:09:06,719
right so these are

1662
01:09:10,630 --> 01:09:08,239
projects for the future and in some

1663
01:09:12,709 --> 01:09:10,640

sense cal is a pathfinder for these kind

1664
01:09:13,669 --> 01:09:12,719
of ideas

1665
01:09:15,749 --> 01:09:13,679
uh

1666
01:09:17,510 --> 01:09:15,759
all these ideas will work better in zero

1667
01:09:19,269 --> 01:09:17,520
gravity uh

1668
01:09:21,189 --> 01:09:19,279
if we could replicate this whole project

1669
01:09:23,669 --> 01:09:21,199
of making bose einstein condensation in

1670
01:09:25,510 --> 01:09:23,679
space they would just hang there

1671
01:09:27,030 --> 01:09:25,520
and uh we could get much colder without

1672
01:09:29,110 --> 01:09:27,040
being bugged by whatever it is we are

1673
01:09:30,709 --> 01:09:29,120
keeping the slow slow-moving atoms from

1674
01:09:32,390 --> 01:09:30,719
just falling which is what happens here

1675
01:09:33,990 --> 01:09:32,400
on earth

1676
01:09:36,229 --> 01:09:34,000
what puts the cold of the cold atom

1677
01:09:38,070 --> 01:09:36,239
laboratory is it because space is cold

1678
01:09:40,550 --> 01:09:38,080
no we've just heard spaces honestly not

1679
01:09:43,510 --> 01:09:40,560
that cold three rays kelvin come on

1680
01:09:45,349 --> 01:09:43,520
um in on earth um

1681
01:09:47,269 --> 01:09:45,359
we have to hold these things in these in

1682
01:09:49,510 --> 01:09:47,279
these magnetic bowls

1683
01:09:51,110 --> 01:09:49,520
and uh i i mentioned five nano kelvin

1684
01:09:52,630 --> 01:09:51,120
which is about as cold

1685
01:09:54,950 --> 01:09:52,640
this is already a very very cold

1686
01:09:56,310 --> 01:09:54,960
temperature on earth not even routinely

1687
01:09:57,669 --> 01:09:56,320
observed

1688
01:09:59,350 --> 01:09:57,679

we learned

1689
01:10:01,750 --> 01:09:59,360
in high school physics that if you take

1690
01:10:03,990 --> 01:10:01,760
a gas and you expand it

1691
01:10:05,910 --> 01:10:04,000
it gets colder right ideal gas law all

1692
01:10:07,750 --> 01:10:05,920
that kind of stuff so we're holding

1693
01:10:09,110 --> 01:10:07,760
these things in a magnetic bowl easiest

1694
01:10:10,709 --> 01:10:09,120
thing in the world in the back for a

1695
01:10:12,790 --> 01:10:10,719
magnetic bowl is to turn down the

1696
01:10:14,630 --> 01:10:12,800
electric current going in the coils the

1697
01:10:17,270 --> 01:10:14,640
magnetic fields get weaker

1698
01:10:19,750 --> 01:10:17,280
the bowl gets goes from a deep bowl like

1699
01:10:21,910 --> 01:10:19,760
say like a tea a tea mug into a shallow

1700
01:10:23,510 --> 01:10:21,920
like a t saucer and you do that

1701
01:10:25,910 --> 01:10:23,520
gradually the atoms expand and they

1702
01:10:28,070 --> 01:10:25,920
should get colder just like you know pv

1703
01:10:30,470 --> 01:10:28,080
equals nkt you know the volume gets

1704
01:10:32,550 --> 01:10:30,480
bigger it should get colder but so why

1705
01:10:34,630 --> 01:10:32,560
don't we just do that and the problem is

1706
01:10:36,070 --> 01:10:34,640
at least here on earth is that the bowl

1707
01:10:37,270 --> 01:10:36,080
doesn't look like that it doesn't look

1708
01:10:39,030 --> 01:10:37,280
like a shallow bowl it looks like a

1709
01:10:40,790 --> 01:10:39,040
shallow bowl tilted on a side this is

1710
01:10:42,630 --> 01:10:40,800
gravity the atoms will slide on out and

1711
01:10:44,630 --> 01:10:42,640
they'll fall out screaming to their to

1712
01:10:45,430 --> 01:10:44,640
their infinite peril and that will be

1713
01:10:47,030 --> 01:10:45,440

that

1714
01:10:48,550 --> 01:10:47,040
where does this how does this connect

1715
01:10:50,390 --> 01:10:48,560
with uh

1716
01:10:51,990 --> 01:10:50,400
with gravity well i think uh christina

1717
01:10:53,669 --> 01:10:52,000
would be the first to tell you that in

1718
01:10:55,189 --> 01:10:53,679
earth in space no one can hear you

1719
01:10:57,110 --> 01:10:55,199
scream so the screaming

1720
01:10:59,350 --> 01:10:57,120
no that's not actually the reason um

1721
01:11:01,350 --> 01:10:59,360
it's actually because

1722
01:11:03,189 --> 01:11:01,360
uh there's effectively no gravity

1723
01:11:05,030 --> 01:11:03,199
basically in space so atoms don't fall

1724
01:11:06,950 --> 01:11:05,040
out of the trap we can basically do this

1725
01:11:09,030 --> 01:11:06,960
adiabatic expansion and get down into

1726
01:11:11,350 --> 01:11:09,040
temperatures that start with a

1727
01:11:14,470 --> 01:11:11,360
a p instead of with n p stands for

1728
01:11:16,470 --> 01:11:14,480
pretty darn cold

1729
01:11:18,550 --> 01:11:16,480
so why go to the trouble

1730
01:11:20,390 --> 01:11:18,560
detecting gravitational waves studying

1731
01:11:22,390 --> 01:11:20,400
the equivalence principle precision

1732
01:11:25,830 --> 01:11:22,400
orology which is a fancy name for really

1733
01:11:27,030 --> 01:11:25,840
good clocks uh dark matter cow will help

1734
01:11:29,350 --> 01:11:27,040
develop all of these relevant

1735
01:11:31,750 --> 01:11:29,360
technologies it's a step in all these

1736
01:11:33,350 --> 01:11:31,760
directions

1737
01:11:35,030 --> 01:11:33,360
we've already seen pictures behind you

1738
01:11:36,390 --> 01:11:35,040

can't see it but behind these folks

1739
01:11:37,910 --> 01:11:36,400
there are two

1740
01:11:41,830 --> 01:11:37,920
optical tables call them think of them

1741
01:11:43,750 --> 01:11:41,840
as large picnic tables full of stuff

1742
01:11:45,030 --> 01:11:43,760
and uh here's actually more modern

1743
01:11:46,790 --> 01:11:45,040
picture

1744
01:11:48,390 --> 01:11:46,800
this shin was one of the grad students

1745
01:11:50,950 --> 01:11:48,400
supported by cal

1746
01:11:53,030 --> 01:11:50,960
and so was vandy here more picnic tables

1747
01:11:54,390 --> 01:11:53,040
more stuff when i first heard about cal

1748
01:11:55,750 --> 01:11:54,400
they said we're gonna take all this

1749
01:11:56,790 --> 01:11:55,760
stuff we're gonna squeeze it all down

1750
01:11:58,390 --> 01:11:56,800
we're gonna put a box and we're gonna

1751
01:11:59,590 --> 01:11:58,400
send it up in a space where no one can

1752
01:12:01,430 --> 01:11:59,600
mess with it for years and years and

1753
01:12:03,590 --> 01:12:01,440
we'll make most einstein conversation

1754
01:12:05,669 --> 01:12:03,600
there and i said yeah right i don't

1755
01:12:07,110 --> 01:12:05,679
think so it's really really hard folks

1756
01:12:09,189 --> 01:12:07,120
this is not gonna it's not something you

1757
01:12:11,030 --> 01:12:09,199
can just like but they uh to my

1758
01:12:12,870 --> 01:12:11,040
astonishment honestly

1759
01:12:13,910 --> 01:12:12,880
uh i was reluctant to get involved in

1760
01:12:15,350 --> 01:12:13,920
the project because i thought there was

1761
01:12:17,750 --> 01:12:15,360
no way in heck this is ever going to

1762
01:12:19,590 --> 01:12:17,760
work but it did which is really pretty

1763
01:12:21,510 --> 01:12:19,600

freaking amazing congratulations cal

1764
01:12:22,550 --> 01:12:21,520
folks that's astonishing can we just

1765
01:12:28,550 --> 01:12:22,560
have a round of applause that was an

1766
01:12:32,470 --> 01:12:30,070
uh and we've heard a little bit about it

1767
01:12:34,229 --> 01:12:32,480
at the heart is a chip which was made by

1768
01:12:36,310 --> 01:12:34,239
a company owned by my pal here dana

1769
01:12:38,070 --> 01:12:36,320
anderson here the chip's about an inch

1770
01:12:40,790 --> 01:12:38,080
on a side i think here at nasa we say

1771
01:12:42,229 --> 01:12:40,800
2.54 centimeters give or take

1772
01:12:44,390 --> 01:12:42,239
and it's got little wires that make the

1773
01:12:47,110 --> 01:12:44,400
magnetic fields for the traps that in

1774
01:12:48,790 --> 01:12:47,120
turn goes into a sort of a scientific

1775
01:12:51,110 --> 01:12:48,800
environment about the size of a loaf of

1776
01:12:53,990 --> 01:12:51,120
bread that thing goes into i always

1777
01:12:55,510 --> 01:12:54,000
think of this as the dorm fridge

1778
01:12:57,350 --> 01:12:55,520
maybe it's more like a hotel fridge it's

1779
01:12:59,110 --> 01:12:57,360
about the size of a dorm fridge i still

1780
01:13:01,430 --> 01:12:59,120
remember my college days when people had

1781
01:13:03,189 --> 01:13:01,440
dorm fridges

1782
01:13:04,790 --> 01:13:03,199
and then that whole thing gets sent up

1783
01:13:06,709 --> 01:13:04,800
into the international space station and

1784
01:13:09,030 --> 01:13:06,719
it's thanks to

1785
01:13:11,430 --> 01:13:09,040
generous funding

1786
01:13:13,350 --> 01:13:11,440
a home and space

1787
01:13:15,030 --> 01:13:13,360
people to design and build this amazing

1788
01:13:18,550 --> 01:13:15,040

thing

1789
01:13:20,390 --> 01:13:18,560
the original truly quantum mechanics who

1790
01:13:22,070 --> 01:13:20,400
who put the thing up on the rack and

1791
01:13:24,070 --> 01:13:22,080
change the oil or whatever it is that

1792
01:13:26,310 --> 01:13:24,080
needs to happen i can't believe i can't

1793
01:13:27,270 --> 01:13:26,320
imagine doing that in space

1794
01:13:29,350 --> 01:13:27,280
and

1795
01:13:32,070 --> 01:13:29,360
but yes turns out as we've heard is

1796
01:13:34,149 --> 01:13:32,080
possible to do keep the thing running

1797
01:13:35,590 --> 01:13:34,159
for the cold adam laboratory

1798
01:13:37,350 --> 01:13:35,600
we've seen some of these pictures

1799
01:13:38,790 --> 01:13:37,360
already

1800
01:13:40,630 --> 01:13:38,800
again these are these pictures are not

1801
01:13:42,229 --> 01:13:40,640
taken in space but again basically they

1802
01:13:44,229 --> 01:13:42,239
turn off the cloud they turn off the

1803
01:13:45,350 --> 01:13:44,239
magnetic trap the atoms just kind of

1804
01:13:47,830 --> 01:13:45,360
hang there

1805
01:13:49,830 --> 01:13:47,840
and they gradually expand because

1806
01:13:51,510 --> 01:13:49,840
they're not exactly at zero temperature

1807
01:13:53,430 --> 01:13:51,520
and after they're expanded for some time

1808
01:13:55,110 --> 01:13:53,440
they take a picture and you see this is

1809
01:13:57,430 --> 01:13:55,120
a representation of the density of the

1810
01:13:59,030 --> 01:13:57,440
cloud and it's getting as it's heading

1811
01:14:00,470 --> 01:13:59,040
towards both einstein condensate it gets

1812
01:14:02,550 --> 01:14:00,480
smaller and smaller and smaller and

1813
01:14:05,270 --> 01:14:02,560

suddenly the spike shows up and those

1814
01:14:07,910 --> 01:14:05,280
spikes like that spike right there is uh

1815
01:14:09,990 --> 01:14:07,920
thousands of atoms all doing all doing

1816
01:14:11,030 --> 01:14:10,000
exactly the same way think of it as like

1817
01:15:16,790 --> 01:14:11,040
a

1818
01:15:19,590 --> 01:15:16,800
zero

1819
01:15:20,870 --> 01:15:19,600
uh for people who who speak metric pico

1820
01:15:23,110 --> 01:15:20,880
is you know

1821
01:15:24,390 --> 01:15:23,120
is to nano as you know micro is to milly

1822
01:15:25,990 --> 01:15:24,400
or whatever it's a thousand times

1823
01:15:27,189 --> 01:15:26,000
smaller these are extraordinarily low

1824
01:15:30,470 --> 01:15:27,199
temperatures

1825
01:15:31,990 --> 01:15:30,480
and made possible by being in space

1826
01:15:33,750 --> 01:15:32,000
um

1827
01:15:35,750 --> 01:15:33,760
this uh people have already alluded to

1828
01:15:38,550 --> 01:15:35,760
this ability to make condensates of two

1829
01:15:39,910 --> 01:15:38,560
different species they appear on one

1830
01:15:41,110 --> 01:15:39,920
side of screen or the other but i want

1831
01:15:42,950 --> 01:15:41,120
to emphasize they're actually sitting

1832
01:15:44,470 --> 01:15:42,960
right on top of each other why would you

1833
01:15:46,550 --> 01:15:44,480
want to do that

1834
01:15:48,229 --> 01:15:46,560
it turns out that

1835
01:15:50,149 --> 01:15:48,239
when you're doing interferometric

1836
01:15:51,430 --> 01:15:50,159
studies for instance of how atoms fall

1837
01:15:52,709 --> 01:15:51,440
under gravity

1838
01:15:54,070 --> 01:15:52,719

there are a lot of possible these are

1839
01:15:55,669 --> 01:15:54,080
precision measurements there's a lot of

1840
01:15:57,590 --> 01:15:55,679
possible sources for air when you make

1841
01:15:59,189 --> 01:15:57,600
precision measurements you'd like to

1842
01:16:00,470 --> 01:15:59,199
cancel out those sources of air and the

1843
01:16:02,390 --> 01:16:00,480
way to do that is by doing a

1844
01:16:04,630 --> 01:16:02,400
differential measurement you measure

1845
01:16:06,310 --> 01:16:04,640
something simultaneously exactly

1846
01:16:09,350 --> 01:16:06,320
overlapping with one species and with

1847
01:16:11,110 --> 01:16:09,360
the other species and most of the errors

1848
01:16:12,630 --> 01:16:11,120
are common mode and subtract out and the

1849
01:16:15,350 --> 01:16:12,640
the physics you want to extract from

1850
01:16:17,270 --> 01:16:15,360
that is it lies in the difference

1851
01:16:18,870 --> 01:16:17,280
uh and i can't can't stop without

1852
01:16:21,350 --> 01:16:18,880
mentioning the experiment i myself am

1853
01:16:22,950 --> 01:16:21,360
working on with my friends my colleagues

1854
01:16:25,189 --> 01:16:22,960
who are here uh

1855
01:16:27,270 --> 01:16:25,199
marin and peter in which we're trying to

1856
01:16:29,110 --> 01:16:27,280
create molecules three atom molecules

1857
01:16:31,750 --> 01:16:29,120
that are about the size of an e coli

1858
01:16:34,630 --> 01:16:31,760
atom so that's like the

1859
01:16:36,870 --> 01:16:34,640
loosest tiniest fluffiest atom molecule

1860
01:16:38,790 --> 01:16:36,880
you've ever seen held together by purely

1861
01:16:40,709 --> 01:16:38,800
quantum mechanical forces we're not

1862
01:16:42,390 --> 01:16:40,719
quite there but soon i hope

1863
01:16:51,669 --> 01:16:42,400

at that point i'm going to stop and

1864
01:16:55,669 --> 01:16:53,270
so folks we are now going to start

1865
01:16:57,430 --> 01:16:55,679
opening it up for q and a q a but as

1866
01:16:59,510 --> 01:16:57,440
they work their way over to their chairs

1867
01:17:01,270 --> 01:16:59,520
over there i want to give a big round of

1868
01:17:03,270 --> 01:17:01,280
applause and a thank you for all of our

1869
01:17:04,790 --> 01:17:03,280
speakers coming from far and wide to be

1870
01:17:06,229 --> 01:17:04,800
here and talk about this amazing mission

1871
01:17:12,950 --> 01:17:06,239
so one big round of applause again for

1872
01:17:17,270 --> 01:17:14,550
our first question we're actually going

1873
01:17:19,189 --> 01:17:17,280
to take from online

1874
01:17:20,630 --> 01:17:19,199
if you're in-house we're going to you

1875
01:17:22,470 --> 01:17:20,640
can step up to the microphones but we'll

1876
01:17:24,870 --> 01:17:22,480
get an online question first we're going

1877
01:17:26,310 --> 01:17:24,880
to go for probably the next 12 13

1878
01:17:28,550 --> 01:17:26,320
minutes if we don't get to your question

1879
01:17:31,669 --> 01:17:28,560
we do apologize for that

1880
01:17:35,430 --> 01:17:31,679
but a question from youtube uh is asked

1881
01:17:36,870 --> 01:17:35,440
how has cal helped us in our daily life

1882
01:17:39,110 --> 01:17:36,880
and i guess which one wants to take this

1883
01:17:40,229 --> 01:17:39,120
one

1884
01:17:42,630 --> 01:17:40,239
oh

1885
01:17:44,550 --> 01:17:42,640
i'll take a crack at it um

1886
01:17:47,910 --> 01:17:44,560
i feel like uh

1887
01:17:50,630 --> 01:17:47,920
so far not so much to be fair

1888
01:17:52,229 --> 01:17:50,640

uh but if the history of technology

1889
01:17:53,669 --> 01:17:52,239
tells us anything it's that the future

1890
01:17:56,310 --> 01:17:53,679
lies in the direction of the very very

1891
01:17:59,669 --> 01:17:56,320
small and um

1892
01:18:01,110 --> 01:17:59,679
our daily lives are improved by so many

1893
01:18:02,470 --> 01:18:01,120
things

1894
01:18:04,149 --> 01:18:02,480
which are involved you know whether

1895
01:18:05,590 --> 01:18:04,159
they're medical devices whether they're

1896
01:18:07,510 --> 01:18:05,600
electronics whether they're computers

1897
01:18:09,590 --> 01:18:07,520
whether it's communication which are

1898
01:18:11,750 --> 01:18:09,600
based on these tiny little chips as they

1899
01:18:13,590 --> 01:18:11,760
get smaller and smaller the rules of

1900
01:18:15,669 --> 01:18:13,600
classical physics no longer apply and

1901
01:18:18,149 --> 01:18:15,679
quantum mechanics take over

1902
01:18:19,830 --> 01:18:18,159
if you want to continue in along this

1903
01:18:21,350 --> 01:18:19,840
trajectory towards making the useful

1904
01:18:24,390 --> 01:18:21,360
things that we want to buy and have in

1905
01:18:26,390 --> 01:18:24,400
our house we need to have a deeper more

1906
01:18:28,470 --> 01:18:26,400
gut level understanding of quantum

1907
01:18:30,149 --> 01:18:28,480
mechanics and there's nothing more gut

1908
01:18:31,910 --> 01:18:30,159
level than just being able to straight

1909
01:18:33,750 --> 01:18:31,920
see a picture of quantum mechanics

1910
01:18:35,910 --> 01:18:33,760
happening so there's a sense in which

1911
01:18:37,669 --> 01:18:35,920
these kind of studies represent a sort

1912
01:18:39,510 --> 01:18:37,679
of

1913
01:18:42,470 --> 01:18:39,520

i don't want to call it a playground but

1914
01:18:44,390 --> 01:18:42,480
uh basically a a working laboratory to

1915
01:18:46,470 --> 01:18:44,400
understand this physics which sort of

1916
01:18:49,189 --> 01:18:46,480
enables so much of the technology that

1917
01:18:51,990 --> 01:18:49,199
is underlies commerce and industry and

1918
01:18:52,830 --> 01:18:52,000
and household products

1919
01:18:54,950 --> 01:18:52,840
very

1920
01:18:57,430 --> 01:18:54,960
cool um we'll go to another question

1921
01:19:00,070 --> 01:18:57,440
from online marina on youtube asks can

1922
01:19:02,149 --> 01:19:00,080
the cold adam lab reconcile and unite

1923
01:19:05,110 --> 01:19:02,159
quantum physics and relativity and

1924
01:19:07,270 --> 01:19:05,120
relativity theory

1925
01:19:09,830 --> 01:19:07,280
yeah i guess i should take that one

1926
01:19:12,149 --> 01:19:09,840
[Laughter]

1927
01:19:17,430 --> 01:19:15,750
all of these technologies are are

1928
01:19:18,630 --> 01:19:17,440
relatively new i would should say

1929
01:19:20,470 --> 01:19:18,640
especially

1930
01:19:22,470 --> 01:19:20,480
the promise that

1931
01:19:24,310 --> 01:19:22,480
we're going to use these cold atoms in

1932
01:19:27,590 --> 01:19:24,320
order to

1933
01:19:29,990 --> 01:19:27,600
make very impactful statements about um

1934
01:19:31,669 --> 01:19:30,000
about fundamental physics it's it's not

1935
01:19:34,310 --> 01:19:31,679
expected that

1936
01:19:35,270 --> 01:19:34,320
cold atom lab in its current state will

1937
01:19:37,430 --> 01:19:35,280
measure

1938
01:19:39,510 --> 01:19:37,440

equivalence principle to date 18 digit

1939
01:19:41,990 --> 01:19:39,520
points or or make some definitive

1940
01:19:43,750 --> 01:19:42,000
statements about uh string theory or

1941
01:19:47,669 --> 01:19:43,760
something like that but

1942
01:19:49,990 --> 01:19:47,679
it is a necessary first step and a large

1943
01:19:53,430 --> 01:19:50,000
leap i would say to to get us there this

1944
01:19:55,750 --> 01:19:53,440
is a technology pathfinder that has

1945
01:19:57,270 --> 01:19:55,760
to me surpassed what the technology we

1946
01:19:58,870 --> 01:19:57,280
were trying to pathfind and is now

1947
01:20:01,590 --> 01:19:58,880
actually has the dual species out of

1948
01:20:04,390 --> 01:20:01,600
interferometry people are some of our

1949
01:20:06,550 --> 01:20:04,400
pis are working on it to actually do

1950
01:20:08,550 --> 01:20:06,560
some preliminary tests of say the

1951
01:20:11,270 --> 01:20:08,560
equivalence principle and and see if

1952
01:20:13,270 --> 01:20:11,280
it's possible and from there we have the

1953
01:20:16,550 --> 01:20:13,280
knowledge now we have that basis to

1954
01:20:18,229 --> 01:20:16,560
build um defined facilities that will be

1955
01:20:19,910 --> 01:20:18,239
able to go in and really probe where we

1956
01:20:22,629 --> 01:20:19,920
need to and understand

1957
01:20:24,470 --> 01:20:22,639
uh and make some definitive statements

1958
01:20:28,550 --> 01:20:24,480
so i would like to add

1959
01:20:32,790 --> 01:20:28,560
if we think of the mars programs like

1960
01:20:35,910 --> 01:20:32,800
recently i mean we've landed two huge

1961
01:20:37,270 --> 01:20:35,920
rovers uh curiosity

1962
01:20:40,550 --> 01:20:37,280
and

1963
01:20:44,310 --> 01:20:40,560

perseverance they're like over 960

1964
01:20:47,750 --> 01:20:44,320
kilograms well we didn't just do it

1965
01:20:49,590 --> 01:20:47,760
just on the first goal we had to send

1966
01:20:52,709 --> 01:20:49,600
like sujourno

1967
01:20:55,030 --> 01:20:52,719
and learn from that then we went to

1968
01:20:57,830 --> 01:20:55,040
mars exploration rovers and john can

1969
01:21:00,149 --> 01:20:57,840
tell you and then we learned

1970
01:21:02,149 --> 01:21:00,159
and we built on this knowledge before we

1971
01:21:03,830 --> 01:21:02,159
could land something that big so i feel

1972
01:21:04,790 --> 01:21:03,840
like the same thing with the cold atom

1973
01:21:08,229 --> 01:21:04,800
lab

1974
01:21:09,830 --> 01:21:08,239
it's uh pathfinder and the ability to be

1975
01:21:12,870 --> 01:21:09,840
able to

1976
01:21:15,830 --> 01:21:12,880
extract like two two separate atoms or

1977
01:21:18,310 --> 01:21:15,840
or cloud of atoms like potassium and

1978
01:21:20,870 --> 01:21:18,320
rubidium and

1979
01:21:22,870 --> 01:21:20,880
potassium is is lighter than rubidium

1980
01:21:25,350 --> 01:21:22,880
and to be able to control and release

1981
01:21:28,390 --> 01:21:25,360
them at the right time and and be able

1982
01:21:31,590 --> 01:21:28,400
to observe which one hits you know the

1983
01:21:33,910 --> 01:21:31,600
the platform first that's a huge leap

1984
01:21:36,390 --> 01:21:33,920
that we couldn't have done uh five years

1985
01:21:37,910 --> 01:21:36,400
ago so anyway thanks i just want to add

1986
01:21:39,510 --> 01:21:37,920
this fantastic we actually have a

1987
01:21:41,510 --> 01:21:39,520
question in the house right now over

1988
01:21:44,550 --> 01:21:41,520

here on the right side

1989
01:21:47,189 --> 01:21:44,560
hello um i was wondering how can you use

1990
01:21:49,669 --> 01:21:47,199
the cold atom lab to understand or

1991
01:21:51,750 --> 01:21:49,679
detect dark matter you guys mentioned

1992
01:21:55,669 --> 01:21:51,760
that it was like related to that but how

1993
01:21:59,669 --> 01:21:57,510
okay yeah i can take a first crack at it

1994
01:22:01,669 --> 01:21:59,679
and i'm happy for anybody else to

1995
01:22:04,390 --> 01:22:01,679
uh to jump into that because this is

1996
01:22:06,390 --> 01:22:04,400
really a branch of research that has

1997
01:22:08,709 --> 01:22:06,400
been a pleasant surprise that has

1998
01:22:12,550 --> 01:22:08,719
cropped up over the last decade or so i

1999
01:22:14,149 --> 01:22:12,560
should say so um dark matter emerges as

2000
01:22:15,990 --> 01:22:14,159
subtle forces in our universe that we

2001
01:22:18,470 --> 01:22:16,000
don't understand um

2002
01:22:19,430 --> 01:22:18,480
and these are um there's been a lot of

2003
01:22:21,590 --> 01:22:19,440
search

2004
01:22:24,470 --> 01:22:21,600
over the last decades for what is the

2005
01:22:27,270 --> 01:22:24,480
essence of dark matter could it be some

2006
01:22:28,629 --> 01:22:27,280
some particle that interacts with matter

2007
01:22:31,990 --> 01:22:28,639
but we can't see

2008
01:22:34,149 --> 01:22:32,000
there is a class of dark matter that is

2009
01:22:36,790 --> 01:22:34,159
ultralight and so the idea that there

2010
01:22:37,910 --> 01:22:36,800
are some very many very light particles

2011
01:22:40,629 --> 01:22:37,920
but enough of them that they're

2012
01:22:42,629 --> 01:22:40,639
pervasive in our universe and the

2013
01:22:45,590 --> 01:22:42,639

influence of these ultralight particles

2014
01:22:47,990 --> 01:22:45,600
might give subtle forces on quantum

2015
01:22:50,229 --> 01:22:48,000
gases that could be perceptible and so

2016
01:22:51,750 --> 01:22:50,239
we could actually have a complementary

2017
01:22:54,390 --> 01:22:51,760
new type of measurement that no other

2018
01:22:56,629 --> 01:22:54,400
apparatus could could possibly be used

2019
01:22:59,750 --> 01:22:56,639
or could possibly see this unique class

2020
01:23:01,510 --> 01:22:59,760
of dark matter that um is feasible uh

2021
01:23:03,189 --> 01:23:01,520
that could explain

2022
01:23:04,229 --> 01:23:03,199
the unknown nature of

2023
01:23:05,669 --> 01:23:04,239
of uh

2024
01:23:08,950 --> 01:23:05,679
strange forces on our universe that

2025
01:23:10,149 --> 01:23:08,960
don't yet have an explanation

2026
01:23:12,229 --> 01:23:10,159
thanks

2027
01:23:14,550 --> 01:23:12,239
very cool we have another question from

2028
01:23:17,270 --> 01:23:14,560
facebook this time um

2029
01:23:19,189 --> 01:23:17,280
this is really focused on atoms is it

2030
01:23:20,790 --> 01:23:19,199
possible to focus on molecules is it

2031
01:23:22,950 --> 01:23:20,800
possible to focus on even more specific

2032
01:23:25,270 --> 01:23:22,960
parts from this point or is atoms kind

2033
01:23:26,149 --> 01:23:25,280
of where we want to be with this

2034
01:23:31,669 --> 01:23:26,159
um

2035
01:23:33,189 --> 01:23:31,679
you have may have heard like

2036
01:23:34,550 --> 01:23:33,199
people haven't talked about it but words

2037
01:23:37,750 --> 01:23:34,560
have appeared of the slides like

2038
01:23:39,910 --> 01:23:37,760

feshbach and ephemoth which sound uh

2039
01:23:42,149 --> 01:23:39,920
you know just like exotic names but in

2040
01:23:44,709 --> 01:23:42,159
in fact they refer really to molecules

2041
01:23:46,390 --> 01:23:44,719
uh feshbach residences are what happens

2042
01:23:47,669 --> 01:23:46,400
when you take two atoms and you adjust

2043
01:23:49,510 --> 01:23:47,679
the magnetic field and they stick

2044
01:23:51,750 --> 01:23:49,520
together to form molecules and these are

2045
01:23:54,229 --> 01:23:51,760
projects which are very much ongoing

2046
01:23:55,669 --> 01:23:54,239
soon i think they'll be making

2047
01:23:57,510 --> 01:23:55,679
molecules

2048
01:23:59,750 --> 01:23:57,520
of okay in this case rubidium and

2049
01:24:02,070 --> 01:23:59,760
potassium stuck together we're working

2050
01:24:03,669 --> 01:24:02,080
on trying to make three potassium atoms

2051
01:24:05,189 --> 01:24:03,679
stuck together into a three atom

2052
01:24:06,310 --> 01:24:05,199
molecule

2053
01:24:07,750 --> 01:24:06,320
and

2054
01:24:09,669 --> 01:24:07,760
these are

2055
01:24:11,189 --> 01:24:09,679
molecules which you know no chemist

2056
01:24:13,110 --> 01:24:11,199
would recognize if you wrote them down

2057
01:24:14,390 --> 01:24:13,120
on your on your on a chemistry exam in

2058
01:24:16,310 --> 01:24:14,400
high school it would be marked wrong

2059
01:24:18,229 --> 01:24:16,320
this is not a molecule you know it

2060
01:24:19,910 --> 01:24:18,239
doesn't obey any of the rules but that's

2061
01:24:21,430 --> 01:24:19,920
sort of what makes them fun is these are

2062
01:24:23,430 --> 01:24:21,440
molecules that violate most of the

2063
01:24:25,030 --> 01:24:23,440

chemistry rules just because they're so

2064
01:24:26,390 --> 01:24:25,040
lightly bound they're sort of little

2065
01:24:28,629 --> 01:24:26,400
balls of fluff

2066
01:24:31,430 --> 01:24:28,639
and they are sort of pure purely quantum

2067
01:24:33,590 --> 01:24:31,440
mechanical objects

2068
01:24:35,510 --> 01:24:33,600
fantastic we do have another question

2069
01:24:37,030 --> 01:24:35,520
here inside the house as well wearing a

2070
01:24:39,590 --> 01:24:37,040
great mars shirt

2071
01:24:42,310 --> 01:24:39,600
hi my name is amy and i'm an engineer on

2072
01:24:43,830 --> 01:24:42,320
the mission ops for march 2020 and i was

2073
01:24:45,430 --> 01:24:43,840
wondering how did you figure out what

2074
01:24:47,350 --> 01:24:45,440
you're most passionate about and do you

2075
01:24:49,510 --> 01:24:47,360
have any advice for navigating your

2076
01:24:50,390 --> 01:24:49,520
career especially for any students in

2077
01:24:51,990 --> 01:24:50,400
the room

2078
01:24:53,910 --> 01:24:52,000
i think everybody can take a crack at

2079
01:24:55,510 --> 01:24:53,920
this one let's start with uh christina

2080
01:24:58,390 --> 01:24:55,520
since you guys took the other hard ones

2081
01:24:59,990 --> 01:24:58,400
i'll i'll take a crack um

2082
01:25:01,830 --> 01:25:00,000
great question

2083
01:25:05,030 --> 01:25:01,840
when i

2084
01:25:07,030 --> 01:25:05,040
found myself at the many many crossroads

2085
01:25:09,270 --> 01:25:07,040
that you you find yourself at in a

2086
01:25:10,950 --> 01:25:09,280
career or in school

2087
01:25:12,470 --> 01:25:10,960
choosing a school choosing a major

2088
01:25:14,390 --> 01:25:12,480

choosing what to do after school

2089
01:25:17,669 --> 01:25:14,400
choosing whether to take time off

2090
01:25:19,590 --> 01:25:17,679
i had that same question how do you know

2091
01:25:21,350 --> 01:25:19,600
the right path how do you know what

2092
01:25:23,750 --> 01:25:21,360
you're truly passionate about and what's

2093
01:25:26,149 --> 01:25:23,760
going to lead you to not only flourish

2094
01:25:27,669 --> 01:25:26,159
the most and get the most rewarding life

2095
01:25:29,110 --> 01:25:27,679
that you can have but to give the most

2096
01:25:30,390 --> 01:25:29,120
back to the world

2097
01:25:31,910 --> 01:25:30,400
and

2098
01:25:34,229 --> 01:25:31,920
one of the things i would always do is

2099
01:25:36,870 --> 01:25:34,239
go back to what

2100
01:25:38,550 --> 01:25:36,880
i imagined for myself there's a quote i

2101
01:25:41,270 --> 01:25:38,560
think it's a thorough quote

2102
01:25:44,070 --> 01:25:41,280
live the life you imagined and that is

2103
01:25:45,990 --> 01:25:44,080
actually something that i think about i

2104
01:25:47,750 --> 01:25:46,000
think about when i was eight what did i

2105
01:25:48,550 --> 01:25:47,760
picture myself doing when i would grow

2106
01:25:51,030 --> 01:25:48,560
up

2107
01:25:51,910 --> 01:25:51,040
and i actually

2108
01:25:54,629 --> 01:25:51,920
would

2109
01:25:56,550 --> 01:25:54,639
remember those memories and try to think

2110
01:25:58,709 --> 01:25:56,560
about how i could create that life and i

2111
01:26:00,790 --> 01:25:58,719
really did see myself

2112
01:26:02,550 --> 01:26:00,800
being a space science nerd

2113
01:26:04,229 --> 01:26:02,560

and even though i grew up in a small

2114
01:26:06,310 --> 01:26:04,239
town in north carolina and i would

2115
01:26:09,030 --> 01:26:06,320
follow that path

2116
01:26:10,470 --> 01:26:09,040
another thing that i say is do what

2117
01:26:12,310 --> 01:26:10,480
scares you

2118
01:26:13,830 --> 01:26:12,320
and what i mean by that is don't take

2119
01:26:15,510 --> 01:26:13,840
unnecessary risk or anything like that

2120
01:26:17,750 --> 01:26:15,520
but um

2121
01:26:19,990 --> 01:26:17,760
think about the things that intrigue you

2122
01:26:21,510 --> 01:26:20,000
but that you feel like are maybe outside

2123
01:26:23,350 --> 01:26:21,520
of your grasp

2124
01:26:25,910 --> 01:26:23,360
and that's the direction you actually

2125
01:26:28,709 --> 01:26:25,920
have to go in not away from

2126
01:26:30,070 --> 01:26:28,719
it turns out that can tell you what

2127
01:26:31,430 --> 01:26:30,080
interests you

2128
01:26:33,830 --> 01:26:31,440
and also where you're going to get the

2129
01:26:35,270 --> 01:26:33,840
most reward out of because it's probably

2130
01:26:37,910 --> 01:26:35,280
challenging and that's why it's a little

2131
01:26:39,669 --> 01:26:37,920
scary and when you do it you actually

2132
01:26:41,270 --> 01:26:39,679
see what you're capable of and you

2133
01:26:42,950 --> 01:26:41,280
probably have pushed yourself to give

2134
01:26:45,430 --> 01:26:42,960
more back to the world those are some of

2135
01:26:47,430 --> 01:26:45,440
my guiding lights

2136
01:26:49,270 --> 01:26:47,440
yeah thank you christian i the only

2137
01:26:51,830 --> 01:26:49,280
thing i would like to add just basically

2138
01:26:52,870 --> 01:26:51,840

what you just said summarize it in the

2139
01:26:55,590 --> 01:26:52,880
fact that

2140
01:26:57,270 --> 01:26:55,600
when you reach outside your comfort zone

2141
01:26:58,310 --> 01:26:57,280
that's when you learn

2142
01:26:59,669 --> 01:26:58,320
and

2143
01:27:02,790 --> 01:26:59,679
that's really

2144
01:27:03,750 --> 01:27:02,800
what you are kind of conveying

2145
01:27:06,149 --> 01:27:03,760
and

2146
01:27:07,430 --> 01:27:06,159
called adam lab is one example because i

2147
01:27:10,470 --> 01:27:07,440
think

2148
01:27:12,310 --> 01:27:10,480
i mean you heard even from eric uh

2149
01:27:14,390 --> 01:27:12,320
like he had doubts

2150
01:27:16,310 --> 01:27:14,400
and uh

2151
01:27:18,950 --> 01:27:16,320
it's good to have doubts because then

2152
01:27:22,070 --> 01:27:18,960
you you set some criteria that you have

2153
01:27:25,830 --> 01:27:22,080
to convince the right people that that

2154
01:27:27,669 --> 01:27:25,840
you have the right plan and so

2155
01:27:29,990 --> 01:27:27,679
many of these missions we've

2156
01:27:32,790 --> 01:27:30,000
accomplished here at jpl when you talk

2157
01:27:35,270 --> 01:27:32,800
to the people they had to step outside

2158
01:27:37,910 --> 01:27:35,280
their comfort zone to think about ideas

2159
01:27:38,950 --> 01:27:37,920
or even how to implement them

2160
01:27:43,189 --> 01:27:38,960
so

2161
01:27:45,030 --> 01:27:43,199
course passion because i mean fact that

2162
01:27:46,550 --> 01:27:45,040
you're here at gpl you must be

2163
01:27:48,229 --> 01:27:46,560

passionate about what you

2164
01:27:50,070 --> 01:27:48,239
what you're doing

2165
01:27:51,669 --> 01:27:50,080
so we've got two last questions in the

2166
01:27:53,030 --> 01:27:51,679
house that we'll get to uh and then

2167
01:27:55,110 --> 01:27:53,040
we'll wrap it up so we'll start over

2168
01:28:00,149 --> 01:27:55,120
here

2169
01:28:02,229 --> 01:28:00,159
jpl so thank you so much for coming and

2170
01:28:04,550 --> 01:28:02,239
speaking we have many of our students in

2171
01:28:07,990 --> 01:28:04,560
the audience today and it's it's really

2172
01:28:09,990 --> 01:28:08,000
important to them to hear you today

2173
01:28:12,629 --> 01:28:10,000
all of your different backgrounds that

2174
01:28:14,790 --> 01:28:12,639
was a great question about about interns

2175
01:28:17,270 --> 01:28:14,800
and i was wondering if you had something

2176
01:28:19,590 --> 01:28:17,280
that you could share just a lash lasting

2177
01:28:21,189 --> 01:28:19,600
piece of advice or um impression about

2178
01:28:22,709 --> 01:28:21,199
each of your you know we have a project

2179
01:28:24,470 --> 01:28:22,719
manager you have a project scientist an

2180
01:28:26,149 --> 01:28:24,480
astronaut a nobel laureate what is

2181
01:28:28,229 --> 01:28:26,159
something that was very impactful like a

2182
01:28:29,910 --> 01:28:28,239
one-liner that they could take with them

2183
01:28:31,510 --> 01:28:29,920
many of them are ending their 10-week

2184
01:28:32,790 --> 01:28:31,520
internships and they're going on to

2185
01:28:34,790 --> 01:28:32,800
their next steps some of them are

2186
01:28:36,149 --> 01:28:34,800
getting extended so just something to

2187
01:28:39,990 --> 01:28:36,159
leave with them as they

2188
01:28:45,510 --> 01:28:41,669

something to continue on as they go into

2189
01:28:50,950 --> 01:28:48,310
okay i'll just give a quick piece of

2190
01:28:51,669 --> 01:28:50,960
advice that i learned that um

2191
01:28:58,070 --> 01:28:51,679
you

2192
01:29:00,149 --> 01:28:58,080
have

2193
01:29:01,590 --> 01:29:00,159
some of them uh people might know when

2194
01:29:03,030 --> 01:29:01,600
they've been in the field for a long

2195
01:29:04,709 --> 01:29:03,040
time but sometimes when people are in

2196
01:29:06,470 --> 01:29:04,719
the field for a long time

2197
01:29:08,629 --> 01:29:06,480
they they have been thinking about their

2198
01:29:11,270 --> 01:29:08,639
own project for a long time and it is

2199
01:29:13,510 --> 01:29:11,280
really beneficial for us to hear your

2200
01:29:15,030 --> 01:29:13,520
insights and your your contributions so

2201
01:29:17,590 --> 01:29:15,040
so yeah never feel

2202
01:29:20,070 --> 01:29:17,600
intimidated

2203
01:29:22,470 --> 01:29:20,080
all right so you've heard about reach

2204
01:29:24,950 --> 01:29:22,480
outside your comfort zone there is one

2205
01:29:27,110 --> 01:29:24,960
other important

2206
01:29:29,590 --> 01:29:27,120
at least lesson for me

2207
01:29:31,350 --> 01:29:29,600
that i'm reminded by this like whether

2208
01:29:33,910 --> 01:29:31,360
you know from a project site or science

2209
01:29:35,430 --> 01:29:33,920
site you have to be

2210
01:29:37,350 --> 01:29:35,440
able to

2211
01:29:40,070 --> 01:29:37,360
recalibrate meaning

2212
01:29:42,950 --> 01:29:40,080
you have to be flexible when you show up

2213
01:29:43,910 --> 01:29:42,960

to work you think that plan a is going

2214
01:29:48,870 --> 01:29:43,920
to work

2215
01:29:51,669 --> 01:29:48,880
then you have to be flexible to always

2216
01:29:54,229 --> 01:29:51,679
turn to plan b or even plan c and not

2217
01:29:55,270 --> 01:29:54,239
let that deter you from the

2218
01:29:57,910 --> 01:29:55,280
goal

2219
01:29:59,510 --> 01:29:57,920
so nothing that we do here

2220
01:30:01,430 --> 01:29:59,520
is kind of something you're gonna find

2221
01:30:03,669 --> 01:30:01,440
in the textbook so you have to figure it

2222
01:30:05,590 --> 01:30:03,679
out on your own and the only thing that

2223
01:30:07,750 --> 01:30:05,600
how you can be successful whether with

2224
01:30:10,629 --> 01:30:07,760
your team you work with or in your

2225
01:30:12,550 --> 01:30:10,639
career you have to be flexible and able

2226
01:30:14,550 --> 01:30:12,560
to recalibrate

2227
01:30:17,030 --> 01:30:14,560
thank you all right our last question of

2228
01:30:18,310 --> 01:30:17,040
the day right over here

2229
01:30:19,750 --> 01:30:18,320
hello i'm

2230
01:30:21,270 --> 01:30:19,760
one of the interns that's finishing in

2231
01:30:23,669 --> 01:30:21,280
two weeks but i did have a quick

2232
01:30:26,070 --> 01:30:23,679
question just about the science so

2233
01:30:27,669 --> 01:30:26,080
so 50 pico kelvins that's pretty cold i

2234
01:30:29,270 --> 01:30:27,679
was wondering if you thought that that's

2235
01:30:30,709 --> 01:30:29,280
something you'd only find in a

2236
01:30:32,550 --> 01:30:30,719
laboratory setting or if there's

2237
01:30:34,149 --> 01:30:32,560
somewhere out in the universe where

2238
01:30:39,110 --> 01:30:34,159

because of natural conditions it happens

2239
01:30:41,750 --> 01:30:40,390
okay so

2240
01:30:43,510 --> 01:30:41,760
if there's uh

2241
01:30:45,830 --> 01:30:43,520
i i don't think it's going to happen in

2242
01:30:47,430 --> 01:30:45,840
a natural way but i don't feel like that

2243
01:30:49,270 --> 01:30:47,440
rules out the possibility it's finding

2244
01:30:50,790 --> 01:30:49,280
elsewhere in the universe if there were

2245
01:30:53,030 --> 01:30:50,800
sort of the

2246
01:30:55,590 --> 01:30:53,040
the asf the alien space

2247
01:30:56,950 --> 01:30:55,600
science foundation on some distant star

2248
01:30:59,110 --> 01:30:56,960
they could they easily could have pico

2249
01:31:01,510 --> 01:30:59,120
kel temperature there or the uh

2250
01:31:04,629 --> 01:31:01,520
or the alien uh administration for

2251
01:31:07,910 --> 01:31:04,639
aeronautics and okay okay nasa with

2252
01:31:09,189 --> 01:31:07,920
anyway uh yeah i think probably if um

2253
01:31:10,629 --> 01:31:09,199
if there's temperatures that's cold

2254
01:31:12,709 --> 01:31:10,639
anywhere other than

2255
01:31:15,189 --> 01:31:12,719
than uh on the international space

2256
01:31:17,350 --> 01:31:15,199
station it's because of an intelligence

2257
01:31:18,709 --> 01:31:17,360
that's made it happen

2258
01:31:20,629 --> 01:31:18,719
make sense thanks

2259
01:31:22,310 --> 01:31:20,639
thank you what a very what an excellent

2260
01:31:24,310 --> 01:31:22,320
final question for today that is all the

2261
01:31:26,550 --> 01:31:24,320
time that we have for questions i want

2262
01:31:29,189 --> 01:31:26,560
to thank once again our speakers for

2263
01:31:30,470 --> 01:31:29,199

joining us today um i want to thank

2264
01:31:32,790 --> 01:31:30,480
everybody behind the scenes that make

2265
01:31:34,550 --> 01:31:32,800
these talks possible thank you to all of

2266
01:31:36,550 --> 01:31:34,560
you and to everyone who asked questions

2267
01:31:38,790 --> 01:31:36,560
online as we say this is your space

2268
01:31:41,590 --> 01:31:38,800
program we want you to stay safe want