PUBLIC LECTURE SERIES

Neutrino Astronomy: A New Window into the Extreme Universe

Featuring Guest Speaker: Marcos Santander

1
00:00:07,110 --> 00:00:04,550
hello everyone welcome to the space

2
00:00:09,270 --> 00:00:07,120
telescope public lecture series

3
00:00:11,910 --> 00:00:09,280
today's talk will focus on neutrino

4
00:00:13,030 --> 00:00:11,920
astronomy a new window into the extreme

5
00:00:15,990 --> 00:00:13,040
universe

6
00:00:19,429 --> 00:00:16,000
our speaker today is dr marco santander

7
00:00:21,590 --> 00:00:19,439
from the university of alabama

8
00:00:23,830 --> 00:00:21,600
my name is dr quinn hart and i'm a

9
00:00:25,509 --> 00:00:23,840
senior education and outreach scientist

10
00:00:27,269 --> 00:00:25,519
in the office of public outreach at the

11
00:00:28,550 --> 00:00:27,279
space telescope science institute in

12
00:00:33,709 --> 00:00:28,560
baltimore

13
00:00:36,229 --> 00:00:33,719

dr frank summers he's taking some

14
00:00:37,670 --> 00:00:36,239
well-deserved time off so i'll be your

15
00:00:39,910 --> 00:00:37,680
host tonight

16
00:00:42,150 --> 00:00:39,920
we couldn't run this lecture series

17
00:00:45,510 --> 00:00:42,160
without the support of our other regular

18
00:00:47,910 --> 00:00:45,520
public lecture series team thomas

19
00:00:50,150 --> 00:00:47,920
marufu and grant justice at space

20
00:00:51,670 --> 00:00:50,160
telescope who make sure that all the

21
00:00:53,110 --> 00:00:51,680
technical details for these events are

22
00:00:54,389 --> 00:00:53,120
running smoothly

23
00:00:56,630 --> 00:00:54,399
this is why we can bring this talk to

24
00:00:58,150 --> 00:00:56,640
you virtually in real time and as a

25
00:01:01,110 --> 00:00:58,160
recording if you're watching at a later

26
00:01:05,109 --> 00:01:02,869
well what are some of the upcoming

27
00:01:07,270 --> 00:01:05,119
public lecture series talks well next

28
00:01:08,950 --> 00:01:07,280
month when dr frank summer returns he

29
00:01:10,950 --> 00:01:08,960
will be your host

30
00:01:13,350 --> 00:01:10,960
and he's going to be your speaker he'll

31
00:01:15,590 --> 00:01:13,360
be talking to you about ada karina a

32
00:01:18,310 --> 00:01:15,600
massive star that has some major past

33
00:01:20,870 --> 00:01:18,320
explosions that might appear like

34
00:01:23,030 --> 00:01:20,880
they're supernova-like but really aren't

35
00:01:24,310 --> 00:01:23,040
and create some amazing nebular features

36
00:01:26,789 --> 00:01:24,320
surrounding it

37
00:01:28,870 --> 00:01:26,799
in june the talk will focus on how we

38
00:01:31,910 --> 00:01:28,880

understand the formation and evolution

39
00:01:33,910 --> 00:01:31,920
of galaxies by dr cameron hummels

40
00:01:35,590 --> 00:01:33,920
now we don't have a talk in july

41
00:01:37,590 --> 00:01:35,600
but we anticipate that the commissioning

42
00:01:40,550 --> 00:01:37,600
of the james webb space telescope will

43
00:01:42,469 --> 00:01:40,560
be concluded and we will see the highly

44
00:01:44,870 --> 00:01:42,479
anticipated release of the first science

45
00:01:46,389 --> 00:01:44,880
images from the telescope so we're

46
00:01:48,710 --> 00:01:46,399
planning a talk in august that will

47
00:01:51,190 --> 00:01:48,720
focus on these first observations from

48
00:01:55,109 --> 00:01:53,270
to learn more about

49
00:01:57,109 --> 00:01:55,119
today's talk

50
00:01:58,630 --> 00:01:57,119
these upcoming talks

51
00:02:00,149 --> 00:01:58,640
you can go to our website where you can

52
00:02:05,270 --> 00:02:00,159
find our links to the webcast our

53
00:02:09,749 --> 00:02:07,590
public dash lectures

54
00:02:11,589 --> 00:02:09,759
you will find links to our webcast and

55
00:02:12,869 --> 00:02:11,599
you you can subscribe to our mailing

56
00:02:14,550 --> 00:02:12,879
list to get

57
00:02:16,550 --> 00:02:14,560
the talk announcements so you don't miss

58
00:02:18,070 --> 00:02:16,560
a thing

59
00:02:19,910 --> 00:02:18,080
if you scroll down on that page you'll

60
00:02:22,470 --> 00:02:19,920
see the list of the upcoming lectures

61
00:02:25,110 --> 00:02:22,480
that i just referenced but you can also

62
00:02:26,309 --> 00:02:25,120
find links to all of our past lectures

63
00:02:28,630 --> 00:02:26,319

here as well

64
00:02:29,990 --> 00:02:28,640
now if you click on read more for any of

65
00:02:32,150 --> 00:02:30,000
the talks

66
00:02:34,630 --> 00:02:32,160
it will bring you to a dedicated page

67
00:02:36,390 --> 00:02:34,640
where you will find the talk

68
00:02:39,430 --> 00:02:36,400
information including the title the

69
00:02:40,869 --> 00:02:39,440
speaker and a description of that talk

70
00:02:43,670 --> 00:02:40,879
you will find the links to all the

71
00:02:46,070 --> 00:02:43,680
recorded talks either through the stsci

72
00:02:47,030 --> 00:02:46,080
webcast or through the youtube channel

73
00:02:48,710 --> 00:02:47,040
here

74
00:02:50,710 --> 00:02:48,720
so welcome to those of you who happen to

75
00:02:53,350 --> 00:02:50,720
be listening to a recorded version of

76
00:02:57,350 --> 00:02:55,270
for our email list you can sign up on

77
00:02:59,830 --> 00:02:57,360
the public lecture series webpage on our

78
00:03:02,949 --> 00:02:59,840
website you can also subscribe to our

79
00:03:05,750 --> 00:03:02,959
youtube channel which is youtube.com

80
00:03:07,990 --> 00:03:05,760
hubble space telescope where you will

81
00:03:09,670 --> 00:03:08,000
get new video notices and reminders of

82
00:03:11,670 --> 00:03:09,680
live events to come

83
00:03:13,430 --> 00:03:11,680
you can also send any comments or

84
00:03:15,910 --> 00:03:13,440
questions about the public

85
00:03:21,430 --> 00:03:15,920
public lecture series itself to public

86
00:03:24,869 --> 00:03:22,949
now if you want to follow us on social

87
00:03:25,670 --> 00:03:24,879
media to learn more about what's going

88
00:03:26,630 --> 00:03:25,680

on

89
00:03:27,990 --> 00:03:26,640
in

90
00:03:30,390 --> 00:03:28,000
the universe

91
00:03:31,430 --> 00:03:30,400
we have social media accounts for hubble

92
00:03:32,789 --> 00:03:31,440
web

93
00:03:36,470 --> 00:03:32,799
and roman

94
00:03:39,030 --> 00:03:36,480
and sdsci the facebook pages names are

95
00:03:42,149 --> 00:03:39,040
there hubble telescope web telescope

96
00:03:43,830 --> 00:03:42,159
nasa roman and stsci we also have

97
00:03:46,550 --> 00:03:43,840
twitter accounts where you can follow

98
00:03:49,750 --> 00:03:46,560
along on the news of the day learn some

99
00:03:50,949 --> 00:03:49,760
more in-depth science uh see news press

100
00:03:53,670 --> 00:03:50,959
releases

101
00:03:56,229 --> 00:03:53,680
a variety of things see a lot of threads

102
00:03:58,070 --> 00:03:56,239
on signs like spectroscopy for example

103
00:04:00,949 --> 00:03:58,080
so our twitter handles are there at

104
00:04:03,190 --> 00:04:00,959
hubble telescope at nasa web at nasa

105
00:04:05,190 --> 00:04:03,200
roman at space telescope

106
00:04:06,949 --> 00:04:05,200
on youtube if you're watching on youtube

107
00:04:09,429 --> 00:04:06,959
you're already on our channel hubble

108
00:04:11,750 --> 00:04:09,439
space telescope and you can also look at

109
00:04:13,750 --> 00:04:11,760
nasa web telescope and then we're also

110
00:04:16,550 --> 00:04:13,760
on instagram at space underscore

111
00:04:17,590 --> 00:04:16,560
telescopes and nasa web

112
00:04:19,909 --> 00:04:17,600
so

113
00:04:21,590 --> 00:04:19,919

plenty of opportunities to

114
00:04:23,510 --> 00:04:21,600
learn about what we're doing over here

115
00:04:25,670 --> 00:04:23,520
with the public lecture series but also

116
00:04:27,430 --> 00:04:25,680
a ways to learn and keep up to date on

117
00:04:29,749 --> 00:04:27,440
what's happening in the news

118
00:04:31,990 --> 00:04:29,759
so speaking about the news let's talk a

119
00:04:33,590 --> 00:04:32,000
little bit about some interesting things

120
00:04:36,150 --> 00:04:33,600
that are happening

121
00:04:39,430 --> 00:04:36,160
since uh frank last talked to you last

122
00:04:40,870 --> 00:04:39,440
month so news from the universe now

123
00:04:43,189 --> 00:04:40,880
i'd like to continue what frank

124
00:04:44,950 --> 00:04:43,199
continued last month which is giving you

125
00:04:48,150 --> 00:04:44,960
some web updates

126
00:04:51,030 --> 00:04:48,160
so web has had a major uh

127
00:04:52,629 --> 00:04:51,040
alignment milestone and many of you may

128
00:04:54,390 --> 00:04:52,639
have already seen this image but have

129
00:04:58,070 --> 00:04:54,400
you had if you have not

130
00:04:59,030 --> 00:04:58,080
this is a telescope alignment evaluation

131
00:05:01,029 --> 00:04:59,040
image

132
00:05:04,150 --> 00:05:01,039
now last month frank showed us that the

133
00:05:06,390 --> 00:05:04,160
18 images of a star was image with web

134
00:05:08,150 --> 00:05:06,400
that's because the 18 hexagonal mirrors

135
00:05:10,710 --> 00:05:08,160
that make up the primary were not

136
00:05:12,230 --> 00:05:10,720
aligned yet so you saw individual images

137
00:05:14,230 --> 00:05:12,240
as the engineers began to move the

138
00:05:16,070 --> 00:05:14,240

mirrors very fine movements they were

139
00:05:17,749 --> 00:05:16,080
able to stack the images to create one

140
00:05:20,070 --> 00:05:17,759
star image

141
00:05:22,710 --> 00:05:20,080
but that stacked image still needed to

142
00:05:25,270 --> 00:05:22,720
be sharpened up so in mid-march the

143
00:05:27,110 --> 00:05:25,280
mirrors were successfully lined with one

144
00:05:28,950 --> 00:05:27,120
of the instruments on web called the

145
00:05:31,189 --> 00:05:28,960
near cam instrument

146
00:05:32,390 --> 00:05:31,199
uh and that's uh

147
00:05:35,270 --> 00:05:32,400
this is how this

148
00:05:38,550 --> 00:05:35,280
image was taken was with that instrument

149
00:05:40,790 --> 00:05:38,560
this star has a very long set of code

150
00:05:41,670 --> 00:05:40,800
names it's two mass

151
00:05:44,469 --> 00:05:41,680
j

152
00:05:45,590 --> 00:05:44,479
one seven five five four zero four two

153
00:05:49,110 --> 00:05:45,600
plus

154
00:05:50,629 --> 00:05:49,120
six six five five one two seven seven

155
00:05:53,350 --> 00:05:50,639
and you might be asking that's a really

156
00:05:55,590 --> 00:05:53,360
long slew of numbers and it's basically

157
00:05:57,270 --> 00:05:55,600
the coordinates of the star of writer's

158
00:05:58,870 --> 00:05:57,280
ascension and declination

159
00:06:01,909 --> 00:05:58,880
the image used

160
00:06:03,909 --> 00:06:01,919
a filter at two microns in the infrared

161
00:06:06,790 --> 00:06:03,919
and it's colorized in this red to

162
00:06:09,029 --> 00:06:06,800
optimize the visual contrast

163
00:06:10,390 --> 00:06:09,039

this beautiful engineering image

164
00:06:12,469 --> 00:06:10,400
shows us that the optics on the

165
00:06:14,230 --> 00:06:12,479
telescope are aligned with the near cam

166
00:06:15,749 --> 00:06:14,240
instrument again this is a major

167
00:06:17,990 --> 00:06:15,759
milestone for the telescope because

168
00:06:20,150 --> 00:06:18,000
every optical parameter of the eyes of

169
00:06:24,309 --> 00:06:20,160
the telescope has been checked out and

170
00:06:26,469 --> 00:06:24,319
it's performing at or above expectations

171
00:06:28,150 --> 00:06:26,479
it's just spectacular it's beautiful to

172
00:06:30,469 --> 00:06:28,160
look at when you say

173
00:06:32,710 --> 00:06:30,479
now again this is is crucial in order to

174
00:06:34,550 --> 00:06:32,720
start future science observations after

175
00:06:36,230 --> 00:06:34,560
the telescope's full commissioning has

176
00:06:39,110 --> 00:06:36,240
concluded

177
00:06:40,710 --> 00:06:39,120
now one thing that pops out at you may

178
00:06:43,590 --> 00:06:40,720
be that

179
00:06:45,830 --> 00:06:43,600
the diffraction spikes on this star

180
00:06:47,510 --> 00:06:45,840
taken by web looks different than the

181
00:06:48,710 --> 00:06:47,520
diffraction spikes on the hubble space

182
00:06:50,870 --> 00:06:48,720
telescope

183
00:06:53,510 --> 00:06:50,880
there are six major spikes on the web

184
00:06:55,189 --> 00:06:53,520
image in contrast to the four spikes you

185
00:06:56,950 --> 00:06:55,199
normally see with a hubble star which

186
00:06:59,189 --> 00:06:56,960
you see on the right there of a variable

187
00:07:00,150 --> 00:06:59,199
star rs

188
00:07:02,150 --> 00:07:00,160

puppis

189
00:07:04,469 --> 00:07:02,160
the difference here is related to the

190
00:07:06,309 --> 00:07:04,479
shape of the primary or the main mirror

191
00:07:08,550 --> 00:07:06,319
on the telescopes and the struts that

192
00:07:11,110 --> 00:07:08,560
hold the secondary mirror

193
00:07:12,950 --> 00:07:11,120
the jwst diffraction spike is a result

194
00:07:15,510 --> 00:07:12,960
of the edges on the outside of the

195
00:07:18,070 --> 00:07:15,520
segmented mirror that uses a hexagonal

196
00:07:20,070 --> 00:07:18,080
um mirrors individual mirrors and the

197
00:07:22,390 --> 00:07:20,080
other minor feature is specifically in

198
00:07:25,430 --> 00:07:22,400
the hub the web image the one goes

199
00:07:27,350 --> 00:07:25,440
across that's kind of faint horizontally

200
00:07:28,950 --> 00:07:27,360
that's related to the support structures

201
00:07:31,990 --> 00:07:28,960
for the secondary mirror

202
00:07:34,070 --> 00:07:32,000
now the other amazing image that really

203
00:07:36,309 --> 00:07:34,080
caught at least my eye was looking at

204
00:07:39,189 --> 00:07:36,319
all the detail in the background of that

205
00:07:42,150 --> 00:07:39,199
star seeing all those specs those are

206
00:07:44,830 --> 00:07:42,160
galaxies now this exp this image

207
00:07:47,670 --> 00:07:44,840
exposure time here is uh

208
00:07:49,990 --> 00:07:47,680
2104 seconds so it's about a 35 minute

209
00:07:51,589 --> 00:07:50,000
exposure

210
00:07:53,350 --> 00:07:51,599
it's really fun following some of the

211
00:07:55,189 --> 00:07:53,360
scientists on twitter going around

212
00:07:57,830 --> 00:07:55,199
looking for previous images of some of

213
00:08:00,070 --> 00:07:57,840

those galaxies and matching up to web so

214
00:08:01,510 --> 00:08:00,080
for those of you who have some free time

215
00:08:03,430 --> 00:08:01,520
on your hands definitely go check that

216
00:08:05,670 --> 00:08:03,440
out

217
00:08:07,430 --> 00:08:05,680
now we can compare the selfie images

218
00:08:08,869 --> 00:08:07,440
that were made with the near cam

219
00:08:10,629 --> 00:08:08,879
instrument on the left you see the

220
00:08:12,309 --> 00:08:10,639
selfie when near cam was completely

221
00:08:13,430 --> 00:08:12,319
aligned to the optical elements of the

222
00:08:15,350 --> 00:08:13,440
telescope

223
00:08:17,670 --> 00:08:15,360
notice that every mirror appears

224
00:08:19,830 --> 00:08:17,680
uniformly illuminated that's part of the

225
00:08:21,589 --> 00:08:19,840
alignment process on the right was the

226
00:08:23,510 --> 00:08:21,599
first mirror selfie where each

227
00:08:25,589 --> 00:08:23,520
individual mirror had not been aligned

228
00:08:28,550 --> 00:08:25,599
yet and so you only saw one of the

229
00:08:30,309 --> 00:08:28,560
mirrors actually um uh pick up light

230
00:08:33,350 --> 00:08:30,319
that went into the camera

231
00:08:35,909 --> 00:08:33,360
so um again that was pre and post full

232
00:08:38,949 --> 00:08:35,919
alignment um on near cam

233
00:08:41,750 --> 00:08:38,959
now what's next well right now is the

234
00:08:42,870 --> 00:08:41,760
multi-instrument multi-field alignment

235
00:08:44,550 --> 00:08:42,880
process

236
00:08:46,310 --> 00:08:44,560
the telescope alignment for the other

237
00:08:48,470 --> 00:08:46,320
instruments started after that first

238
00:08:53,350 --> 00:08:48,480

alignment with the near cam instrument

239
00:08:55,430 --> 00:08:53,360
as of april 1st the fine guidance sensor

240
00:08:58,070 --> 00:08:55,440
so this is on the observatory here so

241
00:09:00,790 --> 00:08:58,080
near cam is aligned with the the mirrors

242
00:09:03,350 --> 00:09:00,800
uh the fine guidance sensor

243
00:09:05,829 --> 00:09:03,360
the near infrared slitless spectrograph

244
00:09:07,430 --> 00:09:05,839
and the near infrared spectrometer have

245
00:09:08,470 --> 00:09:07,440
all been successfully aligned with the

246
00:09:10,230 --> 00:09:08,480
observatory

247
00:09:11,829 --> 00:09:10,240
in the weeks to come the instrument

248
00:09:14,389 --> 00:09:11,839
there in the upper right hand side is

249
00:09:16,790 --> 00:09:14,399
miri the mid infrared instrument it's

250
00:09:18,710 --> 00:09:16,800
still cooling down with active cryogenic

251
00:09:22,070 --> 00:09:18,720
cooling techniques to reach an operating

252
00:09:23,350 --> 00:09:22,080
temperature that's just below 7 kelvin

253
00:09:25,190 --> 00:09:23,360
quite cold

254
00:09:27,110 --> 00:09:25,200
then the telescope optical alignment can

255
00:09:29,269 --> 00:09:27,120
begin for that particular instrument

256
00:09:30,389 --> 00:09:29,279
when that's successful there'll be a key

257
00:09:31,990 --> 00:09:30,399
meeting

258
00:09:34,310 --> 00:09:32,000
we'll be called to confirm the end of

259
00:09:36,389 --> 00:09:34,320
all this telescope alignment and then

260
00:09:37,990 --> 00:09:36,399
the instrument commissioning can begin

261
00:09:40,550 --> 00:09:38,000
so that we can get ready for science

262
00:09:41,430 --> 00:09:40,560
operations uh which can start in the

263
00:09:43,190 --> 00:09:41,440

summer

264
00:09:45,110 --> 00:09:43,200
so there are exciting times here to

265
00:09:47,350 --> 00:09:45,120
watch and to hear about all about this

266
00:09:49,509 --> 00:09:47,360
amazing telescope gearing up to start

267
00:09:51,750 --> 00:09:49,519
studying the universe in unprecedented

268
00:09:54,230 --> 00:09:51,760
ways so our public lecture series will

269
00:09:57,350 --> 00:09:54,240
keep you informed as the results come in

270
00:09:59,509 --> 00:09:57,360
so stay tuned

271
00:10:03,030 --> 00:09:59,519
another piece of news from the universe

272
00:10:05,509 --> 00:10:03,040
here is hubble has broken its own record

273
00:10:06,389 --> 00:10:05,519
and has spotted the faintest star ever

274
00:10:09,190 --> 00:10:06,399
seen

275
00:10:10,949 --> 00:10:09,200
so how's it possible to detect a star so

276
00:10:12,710 --> 00:10:10,959
distant that we're looking so far into

277
00:10:16,790 --> 00:10:12,720
the mass so what you see here on the

278
00:10:20,790 --> 00:10:16,800
left is a large view of a galaxy cluster

279
00:10:24,949 --> 00:10:22,550
it's a collection of hundreds of

280
00:10:26,870 --> 00:10:24,959
galaxies bound together by gravity now

281
00:10:28,550 --> 00:10:26,880
most of the cluster mass is actually in

282
00:10:30,310 --> 00:10:28,560
dark matter but when you take all the

283
00:10:33,350 --> 00:10:30,320
mass that dark matter and the regular

284
00:10:35,750 --> 00:10:33,360
matter it warps or bends the fabric of

285
00:10:37,430 --> 00:10:35,760
space-time so any light source behind

286
00:10:39,910 --> 00:10:37,440
the cluster that passes through the

287
00:10:42,310 --> 00:10:39,920
cluster can appear uh stretched out or

288
00:10:43,110 --> 00:10:42,320

warped to and it also can magnify the

289
00:10:45,430 --> 00:10:43,120
light

290
00:10:47,590 --> 00:10:45,440
this is called gravitational lensing

291
00:10:49,990 --> 00:10:47,600
so when we are seeing the light from a

292
00:10:53,030 --> 00:10:50,000
star nicknamed arendelle

293
00:10:54,870 --> 00:10:53,040
it appears now what i'll do here is

294
00:10:57,030 --> 00:10:54,880
zoom in a little closer to a small

295
00:10:59,430 --> 00:10:57,040
section of that image and you'll notice

296
00:11:02,870 --> 00:10:59,440
this reddish colored arc and this arrow

297
00:11:08,230 --> 00:11:02,880
here is pointing to that furthest star

298
00:11:13,030 --> 00:11:10,710
it's the light has been traveling

299
00:11:16,150 --> 00:11:13,040
through the universe to get to hubble

300
00:11:18,310 --> 00:11:16,160
for the past 12.9 billion years so just

301
00:11:19,590 --> 00:11:18,320
about a billion years after the big bang

302
00:11:21,350 --> 00:11:19,600
and again this was

303
00:11:23,190 --> 00:11:21,360
possible due to a special set of

304
00:11:25,590 --> 00:11:23,200
circumstances so let's break that down

305
00:11:27,750 --> 00:11:25,600
really quickly

306
00:11:29,269 --> 00:11:27,760
so when we take again look at the

307
00:11:31,990 --> 00:11:29,279
close look at one of these warp features

308
00:11:33,829 --> 00:11:32,000
you can see a series of dots the one dot

309
00:11:35,750 --> 00:11:33,839
that's pointed out there is that really

310
00:11:37,670 --> 00:11:35,760
distant star

311
00:11:39,910 --> 00:11:37,680
the warp features here happen to lie

312
00:11:41,829 --> 00:11:39,920
along a line of maximum magnification

313
00:11:44,710 --> 00:11:41,839

called a caustic and the star's

314
00:11:46,630 --> 00:11:44,720
brightness also increased a thousand

315
00:11:48,630 --> 00:11:46,640
fold which is why we can see it at such

316
00:11:50,389 --> 00:11:48,640
a large distance due to this very

317
00:11:51,829 --> 00:11:50,399
perfect alignment with the cluster in

318
00:11:54,069 --> 00:11:51,839
the foreground

319
00:11:57,190 --> 00:11:54,079
the detection surpassed the previous

320
00:11:58,790 --> 00:11:57,200
star distance record by hubble that star

321
00:11:59,990 --> 00:11:58,800
is located a distance so though we're

322
00:12:02,870 --> 00:12:00,000
peering back

323
00:12:05,910 --> 00:12:02,880
only 9.8 billion years into the past

324
00:12:07,350 --> 00:12:05,920
compared to 12.9 billion years here for

325
00:12:09,350 --> 00:12:07,360
for arendelle

326
00:12:11,190 --> 00:12:09,360
the previous record holder was also

327
00:12:13,509 --> 00:12:11,200
detected by a gravitational lensing

328
00:12:15,110 --> 00:12:13,519
effect by a foreground cluster of galax

329
00:12:16,790 --> 00:12:15,120
galaxies now my area of research in the

330
00:12:18,389 --> 00:12:16,800
past has been clusters of galaxies

331
00:12:20,790 --> 00:12:18,399
that's near and dear to my heart so i

332
00:12:22,069 --> 00:12:20,800
love seeing these images

333
00:12:24,389 --> 00:12:22,079
now it's really important to find these

334
00:12:26,470 --> 00:12:24,399
ancient stars because their properties

335
00:12:28,949 --> 00:12:26,480
give us clues into star formation when

336
00:12:31,110 --> 00:12:28,959
the universe was really young

337
00:12:33,590 --> 00:12:31,120
what how how massive were they how

338
00:12:35,670 --> 00:12:33,600

bright were they what were they composed

339
00:12:37,350 --> 00:12:35,680
of was it mostly traces of hydrogen and

340
00:12:38,870 --> 00:12:37,360
helium from

341
00:12:40,870 --> 00:12:38,880
the beginning

342
00:12:43,030 --> 00:12:40,880
of the the universe

343
00:12:45,590 --> 00:12:43,040
did they already have heavy elements

344
00:12:48,069 --> 00:12:45,600
like carbon and nitrogen so researchers

345
00:12:49,829 --> 00:12:48,079
will continue to study arendelle with

346
00:12:51,990 --> 00:12:49,839
the james webb space telescope to

347
00:12:53,990 --> 00:12:52,000
uncover more details and give us some

348
00:12:55,509 --> 00:12:54,000
more answers

349
00:12:57,509 --> 00:12:55,519
so that's the news that i wanted to

350
00:13:00,150 --> 00:12:57,519
share with you today

351
00:13:02,389 --> 00:13:00,160
and now we'll move on here to

352
00:13:03,829 --> 00:13:02,399
i'd like to introduce to you our speaker

353
00:13:05,350 --> 00:13:03,839
so again

354
00:13:08,230 --> 00:13:05,360
tonight we're going to be hearing about

355
00:13:11,350 --> 00:13:08,240
neutrino astronomy a new window into the

356
00:13:13,670 --> 00:13:11,360
extreme universe dr marcos santander

357
00:13:16,150 --> 00:13:13,680
from the university of alabama

358
00:13:18,949 --> 00:13:16,160
so let me

359
00:13:21,990 --> 00:13:18,959
stop sharing my screen here

360
00:13:28,870 --> 00:13:25,829
and i'd like to uh welcome dr santander

361
00:13:30,710 --> 00:13:28,880
to the public lecture series here marcus

362
00:13:33,350 --> 00:13:30,720
was born in the province province of

363
00:13:35,190 --> 00:13:33,360

mendoza argentina near the andes a

364
00:13:37,350 --> 00:13:35,200
region that is best known outside of the

365
00:13:39,750 --> 00:13:37,360
country for its wine production mall

366
00:13:41,670 --> 00:13:39,760
back in particular and i can attest to

367
00:13:43,350 --> 00:13:41,680
the wonderfulness of malbec because i

368
00:13:44,470 --> 00:13:43,360
had a bottle this weekend

369
00:13:46,389 --> 00:13:44,480
with friends

370
00:13:47,670 --> 00:13:46,399
now he earned his bachelor's degree in

371
00:13:50,870 --> 00:13:47,680
engineering from the national

372
00:13:53,350 --> 00:13:50,880
technological ins uh technological

373
00:13:55,110 --> 00:13:53,360
university in argentina he moved to the

374
00:13:58,310 --> 00:13:55,120
university of wisconsin-madison to

375
00:14:01,430 --> 00:13:58,320
purdue pursue a phd in physics working

376
00:14:04,470 --> 00:14:01,440
on the ice cube neutrino observatory he

377
00:14:06,470 --> 00:14:04,480
graduated in 2013 and moved to barnard

378
00:14:08,949 --> 00:14:06,480
college columbia university for a

379
00:14:11,269 --> 00:14:08,959
postdoc in gamma-ray astronomy until

380
00:14:13,269 --> 00:14:11,279
2017 when he joined the faculty at the

381
00:14:14,470 --> 00:14:13,279
university of alabama as an assistant

382
00:14:17,030 --> 00:14:14,480
professor

383
00:14:19,509 --> 00:14:17,040
since then he leads his research group

384
00:14:21,670 --> 00:14:19,519
on the study of neutrino and gamma ray

385
00:14:23,670 --> 00:14:21,680
emission from some of the most powerful

386
00:14:25,509 --> 00:14:23,680
objects in the universe

387
00:14:28,069 --> 00:14:25,519
when not thinking about high-energy

388
00:14:30,389 --> 00:14:28,079

astrophysical sources he also enjoys

389
00:14:32,069 --> 00:14:30,399
astronomy as a hobby looking through his

390
00:14:34,710 --> 00:14:32,079
backyard telescope

391
00:14:36,069 --> 00:14:34,720
beyond astronomy he enjoys photography

392
00:14:38,389 --> 00:14:36,079
playing guitar

393
00:14:40,310 --> 00:14:38,399
watching argentine soccer and most of

394
00:14:43,110 --> 00:14:40,320
all spending time with his daughters

395
00:14:46,629 --> 00:14:43,120
florencia and emma so let's give a warm

396
00:14:50,150 --> 00:14:46,639
welcome to dr santander and uh take it

397
00:14:53,910 --> 00:14:52,389
okay thank you very much dr hart and

398
00:14:54,710 --> 00:14:53,920
it's really a pleasure and honor to be

399
00:14:57,110 --> 00:14:54,720
here

400
00:14:59,509 --> 00:14:57,120
uh talking to you um

401
00:15:01,990 --> 00:14:59,519
i mean at this institute that

402
00:15:04,150 --> 00:15:02,000
meant so much for my formation as i as

403
00:15:06,230 --> 00:15:04,160
even though uh indirectly as you will

404
00:15:07,990 --> 00:15:06,240
learn later on so i'm going to be

405
00:15:10,150 --> 00:15:08,000
talking about nutrient astronomy and

406
00:15:11,350 --> 00:15:10,160
perhaps that's a new topic to this kind

407
00:15:13,670 --> 00:15:11,360
of lectures

408
00:15:15,189 --> 00:15:13,680
and uh i will try to motivate that as a

409
00:15:16,389 --> 00:15:15,199
new way of looking at the extreme

410
00:15:17,829 --> 00:15:16,399
universe and when i talk about the

411
00:15:19,670 --> 00:15:17,839
extreme universe i'm talking mostly

412
00:15:22,150 --> 00:15:19,680
about the highest energies that we can

413
00:15:23,189 --> 00:15:22,160

observe uh from our vantage point in the

414
00:15:25,750 --> 00:15:23,199
universe

415
00:15:26,550 --> 00:15:25,760
and so for the last few centuries we've

416
00:15:28,790 --> 00:15:26,560
been

417
00:15:30,949 --> 00:15:28,800
uh doing astronomy mostly with visible

418
00:15:31,910 --> 00:15:30,959
lights i mean for the last 300 years or

419
00:15:34,310 --> 00:15:31,920
so but

420
00:15:36,629 --> 00:15:34,320
in the 20th century with the development

421
00:15:39,030 --> 00:15:36,639
of electronics and also with development

422
00:15:41,189 --> 00:15:39,040
of new sensor techniques

423
00:15:44,069 --> 00:15:41,199
we've been able to expand that window

424
00:15:44,870 --> 00:15:44,079
into the universe into other wavelengths

425
00:15:47,269 --> 00:15:44,880
that

426
00:15:49,189 --> 00:15:47,279
are not visible to the human eye all the

427
00:15:50,629 --> 00:15:49,199
way from radio with radio telescopes

428
00:15:53,350 --> 00:15:50,639
going through microwave and of course i

429
00:15:55,590 --> 00:15:53,360
have to mention jwst and hubble as the

430
00:15:58,790 --> 00:15:55,600
as the darlings of the of the institute

431
00:16:00,870 --> 00:15:58,800
uh going to higher energies in chandra

432
00:16:02,230 --> 00:16:00,880
uh and gamma rays for instance with our

433
00:16:04,870 --> 00:16:02,240
orbiting satellites and also uh

434
00:16:06,710 --> 00:16:04,880
ground-based sub ground-based telescopes

435
00:16:07,749 --> 00:16:06,720
and out of the entire electromagnetic

436
00:16:09,910 --> 00:16:07,759
spectrum

437
00:16:12,150 --> 00:16:09,920
that spans many many energies many

438
00:16:14,710 --> 00:16:12,160

orders of magnitude energy we only see a

439
00:16:16,310 --> 00:16:14,720
sliver of that with our own eyes and

440
00:16:18,150 --> 00:16:16,320
therefore we want to expand that

441
00:16:19,749 --> 00:16:18,160
especially pushing it towards the higher

442
00:16:20,949 --> 00:16:19,759
energy and in this case in this

443
00:16:23,110 --> 00:16:20,959
electromagnetic spectrum what you're

444
00:16:25,189 --> 00:16:23,120
seeing here the photon energy increases

445
00:16:27,430 --> 00:16:25,199
to the right okay so we're going to try

446
00:16:29,829 --> 00:16:27,440
to push even further to the right to try

447
00:16:31,910 --> 00:16:29,839
to reach the highest observable

448
00:16:34,310 --> 00:16:31,920
things in the universe and why do we do

449
00:16:36,470 --> 00:16:34,320
that because we can study different

450
00:16:38,550 --> 00:16:36,480
phenomena in the universe by looking at

451
00:16:40,150 --> 00:16:38,560
them in different energies and just to

452
00:16:41,430 --> 00:16:40,160
show you kind of an illustration that

453
00:16:43,509 --> 00:16:41,440
each one of these telescopes has a

454
00:16:46,389 --> 00:16:43,519
different sky to look at i wanted to

455
00:16:47,829 --> 00:16:46,399
kind of use an example for

456
00:16:49,990 --> 00:16:47,839
something that you can see with your own

457
00:16:53,110 --> 00:16:50,000
eyes for instance the the big dipper is

458
00:16:56,310 --> 00:16:53,120
a altruism in the northern sky

459
00:16:57,430 --> 00:16:56,320
and if you look at it on any given night

460
00:16:59,910 --> 00:16:57,440
into if you're in the northern

461
00:17:02,949 --> 00:16:59,920
hemisphere you will see uh that what

462
00:17:05,350 --> 00:17:02,959
makes this are discrete points so point

463
00:17:07,029 --> 00:17:05,360

sources of light right and of course we

464
00:17:08,470 --> 00:17:07,039
identify those as stars i mean that's

465
00:17:10,630 --> 00:17:08,480
not surprising

466
00:17:11,990 --> 00:17:10,640
but if we wanted to look at this at very

467
00:17:14,390 --> 00:17:12,000
high energies

468
00:17:15,829 --> 00:17:14,400
uh let me look let me show you the same

469
00:17:18,150 --> 00:17:15,839
patch of sky

470
00:17:20,069 --> 00:17:18,160
but looking at it at in gamma rays with

471
00:17:23,189 --> 00:17:20,079
the fermi space telescope

472
00:17:24,789 --> 00:17:23,199
so this view now is shown only in gamma

473
00:17:26,549 --> 00:17:24,799
rays the colors here indicate different

474
00:17:28,309 --> 00:17:26,559
gamma ray energies and it's the same

475
00:17:30,150 --> 00:17:28,319
patch of sky i haven't changed anything

476
00:17:31,909 --> 00:17:30,160
in the coordinates so if you flip back

477
00:17:34,230 --> 00:17:31,919
and forth you'll notice that there's

478
00:17:35,029 --> 00:17:34,240
nothing that resembles the big dipper in

479
00:17:37,270 --> 00:17:35,039
this

480
00:17:39,990 --> 00:17:37,280
part of the sky and the reason for that

481
00:17:42,070 --> 00:17:40,000
is that now these point sources of light

482
00:17:44,310 --> 00:17:42,080
are not longer

483
00:17:46,390 --> 00:17:44,320
stars they're actually super massive

484
00:17:48,310 --> 00:17:46,400
black holes at the distance of at the

485
00:17:50,870 --> 00:17:48,320
center of distant galaxies

486
00:17:53,029 --> 00:17:50,880
that are accelerating particles and are

487
00:17:55,830 --> 00:17:53,039
shining in gamma rays for instance this

488
00:17:56,950 --> 00:17:55,840

particular one is 8.2 billion light

489
00:17:59,350 --> 00:17:56,960
years away

490
00:18:02,230 --> 00:17:59,360
so that kind of tells us that if we

491
00:18:03,190 --> 00:18:02,240
wanted to look at very high energies you

492
00:18:04,950 --> 00:18:03,200
have to use a different type of

493
00:18:06,950 --> 00:18:04,960
telescope but that will tell you about

494
00:18:09,510 --> 00:18:06,960
something else in the sky that you may

495
00:18:11,590 --> 00:18:09,520
not be able to see with just a visible

496
00:18:14,310 --> 00:18:11,600
light so we want to keep pushing in that

497
00:18:16,549 --> 00:18:14,320
direction towards higher energies okay

498
00:18:18,549 --> 00:18:16,559
so you would say okay we have this great

499
00:18:20,710 --> 00:18:18,559
view of the of the sky with gamma rays

500
00:18:23,190 --> 00:18:20,720
let's keep pushing there let's keep uh

501
00:18:25,590 --> 00:18:23,200
looking at even higher energies in gamma

502
00:18:27,750 --> 00:18:25,600
rays but is unfortunately an issue with

503
00:18:30,230 --> 00:18:27,760
gamma rays is that at some point the

504
00:18:31,270 --> 00:18:30,240
universe actually becomes opaque this

505
00:18:32,950 --> 00:18:31,280
remnant

506
00:18:33,909 --> 00:18:32,960
light from the first generations of

507
00:18:36,390 --> 00:18:33,919
stars

508
00:18:38,950 --> 00:18:36,400
there's also remnant radiation from the

509
00:18:41,110 --> 00:18:38,960
cosmic uh from the big bang called the

510
00:18:43,029 --> 00:18:41,120
cosmic microwave background and that

511
00:18:45,590 --> 00:18:43,039
actually acts as a fog

512
00:18:48,150 --> 00:18:45,600
in the uh in the universe that prevents

513
00:18:49,669 --> 00:18:48,160

the propagation of gamma rays over very

514
00:18:52,549 --> 00:18:49,679
long distances

515
00:18:55,029 --> 00:18:52,559
so at energies that i'm going to measure

516
00:18:57,669 --> 00:18:55,039
in units of electron volt is a perhaps

517
00:18:59,990 --> 00:18:57,679
not a very popular unit of measurement

518
00:19:01,350 --> 00:19:00,000
for energy of photons but just to give

519
00:19:02,870 --> 00:19:01,360
you an indication of what we're going to

520
00:19:05,510 --> 00:19:02,880
be talking about the light that we see

521
00:19:08,310 --> 00:19:05,520
with our own eyes has a an energy of

522
00:19:10,789 --> 00:19:08,320
about one electron volt okay so when i

523
00:19:12,789 --> 00:19:10,799
show here things that have one mega

524
00:19:14,710 --> 00:19:12,799
electron volts meaning 10 to the six or

525
00:19:17,190 --> 00:19:14,720
one million electron volts that means

526
00:19:18,390 --> 00:19:17,200
that that light has energies of about a

527
00:19:21,190 --> 00:19:18,400
million times

528
00:19:22,630 --> 00:19:21,200
uh the energy of visible light

529
00:19:24,070 --> 00:19:22,640
very well so

530
00:19:25,830 --> 00:19:24,080
as i mentioned before i want to keep

531
00:19:27,510 --> 00:19:25,840
pushing to the right in this kind of a

532
00:19:29,990 --> 00:19:27,520
plot so that i can see things with

533
00:19:32,710 --> 00:19:30,000
higher and higher energies and

534
00:19:34,950 --> 00:19:32,720
um as you can see here this kind of blue

535
00:19:36,789 --> 00:19:34,960
blob is showing me where i can no longer

536
00:19:38,549 --> 00:19:36,799
see into the universe because the

537
00:19:40,870 --> 00:19:38,559
universe becomes opaque

538
00:19:42,150 --> 00:19:40,880

and at energies of about 10 to the 15

539
00:19:44,310 --> 00:19:42,160
electron volts

540
00:19:45,750 --> 00:19:44,320
one beta electron volt i cannot even see

541
00:19:47,590 --> 00:19:45,760
all the way to the galactic center i

542
00:19:50,070 --> 00:19:47,600
mean you can go out in the southern

543
00:19:52,950 --> 00:19:50,080
hemisphere look at sagittarius and you

544
00:19:54,710 --> 00:19:52,960
will see kind of the the the group of

545
00:19:55,830 --> 00:19:54,720
stars in the night sky

546
00:19:58,070 --> 00:19:55,840
um

547
00:20:00,390 --> 00:19:58,080
that are kind of towards the galactic

548
00:20:02,149 --> 00:20:00,400
center but you cannot do that with this

549
00:20:03,909 --> 00:20:02,159
very high energy gamma rays and

550
00:20:06,070 --> 00:20:03,919
therefore we want to use something else

551
00:20:08,630 --> 00:20:06,080
we'll explore the highest energies

552
00:20:10,950 --> 00:20:08,640
observable in the universe really to

553
00:20:12,870 --> 00:20:10,960
look not only high energy but also very

554
00:20:15,029 --> 00:20:12,880
deep in the universe

555
00:20:16,870 --> 00:20:15,039
and let me put together kind of uh what

556
00:20:18,710 --> 00:20:16,880
i will think would be the ideal

557
00:20:20,390 --> 00:20:18,720
messenger from the high-energy universe

558
00:20:22,310 --> 00:20:20,400
if we wanted to put together a particle

559
00:20:24,310 --> 00:20:22,320
that can transmit that energy that can

560
00:20:25,909 --> 00:20:24,320
transmit that information from these

561
00:20:27,590 --> 00:20:25,919
sources

562
00:20:29,510 --> 00:20:27,600
i would say that

563
00:20:31,830 --> 00:20:29,520

it would have to be neutral electrically

564
00:20:33,830 --> 00:20:31,840
neutral because charged particles are

565
00:20:35,430 --> 00:20:33,840
bent by magnetic fields and we know that

566
00:20:37,750 --> 00:20:35,440
there are magnetic fields in our galaxy

567
00:20:39,510 --> 00:20:37,760
and also between galaxies and therefore

568
00:20:41,110 --> 00:20:39,520
their paths are bent and we cannot do

569
00:20:43,190 --> 00:20:41,120
astronomy like that because by the time

570
00:20:44,549 --> 00:20:43,200
they reach you those charged particles

571
00:20:46,390 --> 00:20:44,559
would have traveled on kind of a

572
00:20:47,750 --> 00:20:46,400
wandering path and they will not point

573
00:20:49,750 --> 00:20:47,760
back to the source which is a kind of a

574
00:20:50,470 --> 00:20:49,760
requirement for two gastronomy

575
00:20:51,590 --> 00:20:50,480
so

576
00:20:52,789 --> 00:20:51,600
they would have to be electrically

577
00:20:54,549 --> 00:20:52,799
neutral

578
00:20:56,070 --> 00:20:54,559
they will also have to propagate over

579
00:20:58,549 --> 00:20:56,080
long distances without the gain there

580
00:21:00,789 --> 00:20:58,559
are many particles out there

581
00:21:03,590 --> 00:21:00,799
in the kind of the um in particle

582
00:21:05,750 --> 00:21:03,600
physics that are neutral but they decay

583
00:21:07,190 --> 00:21:05,760
very quickly and we want that these

584
00:21:09,029 --> 00:21:07,200
particles don't decay while they're

585
00:21:11,669 --> 00:21:09,039
traveling to us or the way otherwise

586
00:21:13,909 --> 00:21:11,679
we'll lose that information

587
00:21:15,909 --> 00:21:13,919
we also want to have a low probability

588
00:21:18,789 --> 00:21:15,919

of being absorbed so that nothing in

589
00:21:20,630 --> 00:21:18,799
between that source and us can block

590
00:21:22,789 --> 00:21:20,640
that information

591
00:21:24,470 --> 00:21:22,799
and finally we want them to be unique

592
00:21:26,710 --> 00:21:24,480
because we already have a view of the

593
00:21:27,990 --> 00:21:26,720
high-energy sky already in some to some

594
00:21:31,590 --> 00:21:28,000
extent

595
00:21:32,950 --> 00:21:31,600
from light alone but we want that uh

596
00:21:34,710 --> 00:21:32,960
information to provide kind of a

597
00:21:37,350 --> 00:21:34,720
complementary view of the universe that

598
00:21:38,710 --> 00:21:37,360
we can join together with

599
00:21:40,470 --> 00:21:38,720
with photons

600
00:21:42,630 --> 00:21:40,480
so that they can provide a different

601
00:21:45,110 --> 00:21:42,640
type of information so with that

602
00:21:47,029 --> 00:21:45,120
wishlist you look at the particles that

603
00:21:49,110 --> 00:21:47,039
are out there in the in particle physics

604
00:21:50,630 --> 00:21:49,120
that are known and actually there is one

605
00:21:52,950 --> 00:21:50,640
that works great and that is the

606
00:21:55,909 --> 00:21:52,960
neutrino okay so we'll introduce very

607
00:21:57,590 --> 00:21:55,919
briefly the neutrinos so neutrinos are

608
00:21:59,990 --> 00:21:57,600
neutral particles they're elementary

609
00:22:03,830 --> 00:22:00,000
particles and they have a very low very

610
00:22:05,830 --> 00:22:03,840
small but non-zero mass okay so as far

611
00:22:08,149 --> 00:22:05,840
as we know they're elementary particles

612
00:22:11,669 --> 00:22:08,159
and they were first proposed in 1930s

613
00:22:13,990 --> 00:22:11,679

and but they were first detected in 1956

614
00:22:15,430 --> 00:22:14,000
and that delay between proposal and

615
00:22:17,750 --> 00:22:15,440
detection has a good

616
00:22:19,029 --> 00:22:17,760
um has a good reason once i tell you a

617
00:22:20,950 --> 00:22:19,039
little bit more about them why they are

618
00:22:22,789 --> 00:22:20,960
so hard to detect

619
00:22:25,110 --> 00:22:22,799
what are some of the sources that

620
00:22:26,470 --> 00:22:25,120
produce neutrinos that we know of

621
00:22:29,350 --> 00:22:26,480
we know that they're producing

622
00:22:30,630 --> 00:22:29,360
radioactive decays both on the ground on

623
00:22:33,990 --> 00:22:30,640
the ground

624
00:22:35,990 --> 00:22:34,000
on the rock and even in nuclear reactors

625
00:22:37,750 --> 00:22:36,000
and here you have a map of neutrinos

626
00:22:40,549 --> 00:22:37,760
being produced by

627
00:22:42,950 --> 00:22:40,559
by the rock in our planet but also by

628
00:22:45,590 --> 00:22:42,960
nuclear reactors so on top of just the

629
00:22:47,430 --> 00:22:45,600
exposed rock of of the planet you will

630
00:22:49,270 --> 00:22:47,440
see that some parts of the us and some

631
00:22:50,470 --> 00:22:49,280
parts of europe are very dark and that's

632
00:22:52,830 --> 00:22:50,480
mostly because there are nuclear

633
00:22:56,310 --> 00:22:52,840
reactors there that emit many

634
00:22:57,590 --> 00:22:56,320
neutrinos even a banana is a neutrino

635
00:22:59,510 --> 00:22:57,600
emitter

636
00:23:01,430 --> 00:22:59,520
there's potassium 40 in the bananas and

637
00:23:03,909 --> 00:23:01,440
they decay and about a regular-sized

638
00:23:06,630 --> 00:23:03,919

banana will have about 14 neutrinos

639
00:23:07,990 --> 00:23:06,640
emitted every second and as you may

640
00:23:09,830 --> 00:23:08,000
notice you don't see anything coming out

641
00:23:11,510 --> 00:23:09,840
of them and that will become clear in a

642
00:23:14,070 --> 00:23:11,520
second why that is

643
00:23:15,990 --> 00:23:14,080
the sun is perhaps one of the strongest

644
00:23:17,990 --> 00:23:16,000
sources of neutrinos we know of is that

645
00:23:20,070 --> 00:23:18,000
the strongest one that we can detect

646
00:23:21,830 --> 00:23:20,080
and this picture that i'm showing here

647
00:23:24,390 --> 00:23:21,840
is a picture of the sun not taken in

648
00:23:26,950 --> 00:23:24,400
light but taken in neutrinos figuring

649
00:23:29,510 --> 00:23:26,960
out where the neutrinos uh were coming

650
00:23:31,029 --> 00:23:29,520
from the sky and they point back uh to

651
00:23:33,669 --> 00:23:31,039
the sun

652
00:23:37,669 --> 00:23:33,679
every second every square centimeter of

653
00:23:40,070 --> 00:23:37,679
the earth is uh is swept by about 100

654
00:23:41,909 --> 00:23:40,080
billion neutrinos coming from the sun

655
00:23:43,510 --> 00:23:41,919
and as you can probably tell by looking

656
00:23:45,190 --> 00:23:43,520
at this presentation nothing happening

657
00:23:47,190 --> 00:23:45,200
right now

658
00:23:49,750 --> 00:23:47,200
there they cannot be

659
00:23:51,830 --> 00:23:49,760
i mean this cannot be noticed so easily

660
00:23:54,789 --> 00:23:51,840
but we'll talk about bit more about why

661
00:23:57,190 --> 00:23:54,799
that is and so far beyond just the sun

662
00:23:59,269 --> 00:23:57,200
we also know at least one

663
00:24:02,149 --> 00:23:59,279

more source that was detected in 20 and

664
00:24:04,070 --> 00:24:02,159
sorry in 1987 that was a supernova is

665
00:24:06,870 --> 00:24:04,080
the death of a massive star where there

666
00:24:08,950 --> 00:24:06,880
is a core collapse and therefore

667
00:24:11,350 --> 00:24:08,960
in that core collapse there are particle

668
00:24:13,350 --> 00:24:11,360
interactions that lead to a very large

669
00:24:16,149 --> 00:24:13,360
emission of neutrinos so what you see

670
00:24:19,350 --> 00:24:16,159
here is a detector that was operating in

671
00:24:20,310 --> 00:24:19,360
japan in the mine of camioca

672
00:24:25,029 --> 00:24:20,320
and

673
00:24:27,430 --> 00:24:25,039
that overall the detector was uh

674
00:24:29,110 --> 00:24:27,440
detecting events at a certain rate and

675
00:24:32,549 --> 00:24:29,120
there was a huge spike

676
00:24:34,470 --> 00:24:32,559
so that was when the the

677
00:24:35,909 --> 00:24:34,480
the plane of neutrinos coming from that

678
00:24:37,430 --> 00:24:35,919
supernova that happened in the large

679
00:24:39,750 --> 00:24:37,440
magellanic cloud

680
00:24:41,909 --> 00:24:39,760
uh swept the earth and we were able to

681
00:24:42,789 --> 00:24:41,919
detect uh several of them

682
00:24:44,549 --> 00:24:42,799
okay

683
00:24:45,990 --> 00:24:44,559
so most of these neutrinos that i

684
00:24:47,510 --> 00:24:46,000
mentioned here the ones from radioactive

685
00:24:50,789 --> 00:24:47,520
decays the one from bananas the one from

686
00:24:52,710 --> 00:24:50,799
the sun the one from the supernova 1987a

687
00:24:54,549 --> 00:24:52,720
have energies of about a million times

688
00:24:56,950 --> 00:24:54,559

the energy of visible light so what

689
00:24:59,430 --> 00:24:56,960
about one mev right mega electron volts

690
00:25:01,029 --> 00:24:59,440
which means one million times that

691
00:25:03,669 --> 00:25:01,039
but

692
00:25:05,269 --> 00:25:03,679
we want to go even further with that

693
00:25:07,029 --> 00:25:05,279
so i will say a little bit more about

694
00:25:08,950 --> 00:25:07,039
neutrinos because they're important to

695
00:25:10,549 --> 00:25:08,960
understand why it's so challenging to

696
00:25:12,950 --> 00:25:10,559
detect them as i said they have a very

697
00:25:14,390 --> 00:25:12,960
small mass it's non-zero we haven't been

698
00:25:16,549 --> 00:25:14,400
able to even measure it but we know it's

699
00:25:17,350 --> 00:25:16,559
nonzero

700
00:25:19,510 --> 00:25:17,360
this

701
00:25:21,510 --> 00:25:19,520
super tiny number 10 to the minus 36

702
00:25:23,830 --> 00:25:21,520
kilograms is just the limit that we have

703
00:25:26,070 --> 00:25:23,840
said on the mass of the of the neutrino

704
00:25:28,710 --> 00:25:26,080
we don't you don't even know it yet

705
00:25:31,029 --> 00:25:28,720
but just to put that in context the next

706
00:25:32,870 --> 00:25:31,039
lightest elementary particle that has

707
00:25:35,909 --> 00:25:32,880
mass is the electron that has more than

708
00:25:37,510 --> 00:25:35,919
500 000 times the mass of the neutrinos

709
00:25:38,630 --> 00:25:37,520
at least because we don't even know that

710
00:25:40,230 --> 00:25:38,640
yet

711
00:25:41,830 --> 00:25:40,240
the other we think about the neutrinos

712
00:25:44,549 --> 00:25:41,840
is that they come in three flavors that

713
00:25:46,149 --> 00:25:44,559

we call electron tau and muon

714
00:25:48,470 --> 00:25:46,159
this may sound weird because we use the

715
00:25:50,310 --> 00:25:48,480
word flavor in particle physics but it's

716
00:25:52,470 --> 00:25:50,320
kind of a charge like we have positive

717
00:25:54,390 --> 00:25:52,480
charges and negative charges these are

718
00:25:56,230 --> 00:25:54,400
three different types of charges but the

719
00:25:58,230 --> 00:25:56,240
weird thing about neutrinos is that they

720
00:26:00,549 --> 00:25:58,240
change from one type of charge one of

721
00:26:02,149 --> 00:26:00,559
these flavors into another as they fly

722
00:26:04,310 --> 00:26:02,159
they're all neutrino

723
00:26:06,710 --> 00:26:04,320
uh but they can change from one property

724
00:26:08,390 --> 00:26:06,720
to the other uh as they propagate i mean

725
00:26:11,350 --> 00:26:08,400
this will be as weird as i don't know a

726
00:26:14,149 --> 00:26:11,360
bad uh or or not let's say not let's say

727
00:26:15,669 --> 00:26:14,159
a bad but an owl flying into an eagle

728
00:26:18,070 --> 00:26:15,679
flying into a dove i mean there will

729
00:26:20,230 --> 00:26:18,080
always be uh birds but they're

730
00:26:22,549 --> 00:26:20,240
oscillating in their type one from

731
00:26:24,549 --> 00:26:22,559
another as they fly that that's what

732
00:26:25,430 --> 00:26:24,559
neutrinos can do

733
00:26:27,430 --> 00:26:25,440
and the

734
00:26:28,870 --> 00:26:27,440
thing that makes them so hard to detect

735
00:26:31,029 --> 00:26:28,880
is really that they only interact

736
00:26:32,870 --> 00:26:31,039
through what we call the weak force

737
00:26:35,029 --> 00:26:32,880
and the probability of having one of

738
00:26:37,909 --> 00:26:35,039

these interactions is extremely small

739
00:26:39,350 --> 00:26:37,919
and that's how 100 billion neutrinos can

740
00:26:41,190 --> 00:26:39,360
fly from the sun

741
00:26:43,750 --> 00:26:41,200
through our each centimeter square of

742
00:26:46,630 --> 00:26:43,760
our bodies without us noticing it okay

743
00:26:48,630 --> 00:26:46,640
so even with about 10 to the 15 sorry

744
00:26:50,070 --> 00:26:48,640
that's 10 to the 15 not billion but 10

745
00:26:52,630 --> 00:26:50,080
to the 15 neutrinos going through our

746
00:26:54,789 --> 00:26:52,640
body over our entire lifetime this is

747
00:26:56,390 --> 00:26:54,799
only a 50 50 chance that one of them of

748
00:26:58,149 --> 00:26:56,400
this 10 to the 15 neutrinos will

749
00:27:00,950 --> 00:26:58,159
interact with our body so you can

750
00:27:02,390 --> 00:27:00,960
imagine how hard it is to catch them

751
00:27:04,549 --> 00:27:02,400
and just to

752
00:27:06,230 --> 00:27:04,559
lead to the next topic i will mention

753
00:27:08,630 --> 00:27:06,240
this this is kind of a particle physics

754
00:27:10,230 --> 00:27:08,640
diagrams i will only say here that

755
00:27:11,669 --> 00:27:10,240
whenever neutrino interacts there are

756
00:27:13,430 --> 00:27:11,679
some of these nutrient interactions that

757
00:27:14,870 --> 00:27:13,440
lead to the production of a charged

758
00:27:16,630 --> 00:27:14,880
particle that's the only important thing

759
00:27:18,070 --> 00:27:16,640
about these interactions because that

760
00:27:20,789 --> 00:27:18,080
will be important for the detection of

761
00:27:24,149 --> 00:27:20,799
these neutrinos okay so how do we detect

762
00:27:26,470 --> 00:27:24,159
neutrinos if we have a chance in two

763
00:27:27,669 --> 00:27:26,480

that all of all those neutrinos that go

764
00:27:28,470 --> 00:27:27,679
through our body

765
00:27:30,310 --> 00:27:28,480
uh

766
00:27:31,190 --> 00:27:30,320
over a lifetime let's say 70-something

767
00:27:33,510 --> 00:27:31,200
years

768
00:27:35,110 --> 00:27:33,520
uh if you only have like a 50-50 chance

769
00:27:36,389 --> 00:27:35,120
that one of them will be

770
00:27:38,149 --> 00:27:36,399
interacting with our body you can

771
00:27:39,750 --> 00:27:38,159
imagine that it will be very hard to

772
00:27:42,230 --> 00:27:39,760
wait a long time to detect enough

773
00:27:44,710 --> 00:27:42,240
neutrinos to do anything with them

774
00:27:46,630 --> 00:27:44,720
so you really want a massive massive

775
00:27:48,789 --> 00:27:46,640
object to put in front of the neutrinos

776
00:27:51,590 --> 00:27:48,799
so that you have that interaction

777
00:27:52,870 --> 00:27:51,600
probability be larger because so rarely

778
00:27:54,870 --> 00:27:52,880
it happens

779
00:27:57,510 --> 00:27:54,880
and here i'm showing you a picture of

780
00:27:59,750 --> 00:27:57,520
one of the biggest is the biggest uh

781
00:28:01,669 --> 00:27:59,760
let's say a human built

782
00:28:03,830 --> 00:28:01,679
neutrino telescope is called the super

783
00:28:06,470 --> 00:28:03,840
coming candy detectors in japan

784
00:28:09,830 --> 00:28:06,480
it has a diameter of almost 40 meters

785
00:28:11,590 --> 00:28:09,840
and a height of also 40 meters and what

786
00:28:14,470 --> 00:28:11,600
you see here on the walls are light

787
00:28:15,909 --> 00:28:14,480
sensors and this white figures that you

788
00:28:17,990 --> 00:28:15,919

see in this platform these are human

789
00:28:20,070 --> 00:28:18,000
beings so you can imagine what the scale

790
00:28:21,830 --> 00:28:20,080
of this thing is

791
00:28:24,070 --> 00:28:21,840
so um

792
00:28:25,590 --> 00:28:24,080
as i said uh whenever a neutrino

793
00:28:27,190 --> 00:28:25,600
interacts sometimes it will produce

794
00:28:28,870 --> 00:28:27,200
charged particles and these charged

795
00:28:30,630 --> 00:28:28,880
particles now become visible because

796
00:28:32,230 --> 00:28:30,640
they can interact through

797
00:28:33,750 --> 00:28:32,240
the electromagnetic force which is much

798
00:28:34,950 --> 00:28:33,760
stronger than the weak force as the name

799
00:28:36,230 --> 00:28:34,960
implies

800
00:28:37,669 --> 00:28:36,240
uh discharge particles that are

801
00:28:39,669 --> 00:28:37,679
producing these nutrient interactions

802
00:28:41,909 --> 00:28:39,679
travel faster than the speed of light in

803
00:28:44,230 --> 00:28:41,919
water because at some point this whole

804
00:28:45,590 --> 00:28:44,240
detector will be filled with water and

805
00:28:48,149 --> 00:28:45,600
when that happens

806
00:28:49,990 --> 00:28:48,159
this is what we call uh the emission of

807
00:28:51,669 --> 00:28:50,000
a type of light that we call trench of

808
00:28:55,029 --> 00:28:51,679
radiation or check on light that's kind

809
00:28:57,430 --> 00:28:55,039
of a blue or uv light that's emitted on

810
00:28:59,750 --> 00:28:57,440
a cone okay it's kind of similar to a

811
00:29:02,549 --> 00:28:59,760
sonic boom from a plane uh but it

812
00:29:04,789 --> 00:29:02,559
happens with light instead of sound

813
00:29:07,269 --> 00:29:04,799

and that particular cone has a very

814
00:29:09,190 --> 00:29:07,279
specific geometry that we can calculate

815
00:29:12,789 --> 00:29:09,200
based on the properties of water

816
00:29:15,830 --> 00:29:12,799
so based on the lights that all of these

817
00:29:17,029 --> 00:29:15,840
side sensors in the japanese detector

818
00:29:19,990 --> 00:29:17,039
detect

819
00:29:22,789 --> 00:29:20,000
and based on their uh on the on the side

820
00:29:25,190 --> 00:29:22,799
of the on the on the shape of that cone

821
00:29:27,510 --> 00:29:25,200
we can infer the direction the energy

822
00:29:29,110 --> 00:29:27,520
and other properties of the neutrinos

823
00:29:30,710 --> 00:29:29,120
you may have seen sometimes strength of

824
00:29:33,029 --> 00:29:30,720
light without knowing it if you have

825
00:29:35,110 --> 00:29:33,039
seen a picture of a nuclear reactor that

826
00:29:37,590 --> 00:29:35,120
is operating you will see some kind of

827
00:29:39,350 --> 00:29:37,600
bluish

828
00:29:40,789 --> 00:29:39,360
glow coming out of it and that's

829
00:29:42,310 --> 00:29:40,799
actually trunk of light being produced

830
00:29:44,470 --> 00:29:42,320
by charged particles

831
00:29:46,870 --> 00:29:44,480
in the reactor pool

832
00:29:49,110 --> 00:29:46,880
so uh as i said these light sensors that

833
00:29:51,350 --> 00:29:49,120
you see kind of uh covering the walls

834
00:29:53,990 --> 00:29:51,360
and the the the floor and the and the

835
00:29:56,230 --> 00:29:54,000
ceiling of this detector they record the

836
00:29:57,830 --> 00:29:56,240
strength of photons coming from not the

837
00:29:59,750 --> 00:29:57,840
neutrino itself but the particles

838
00:30:01,750 --> 00:29:59,760

produced by the nuclear interaction and

839
00:30:03,510 --> 00:30:01,760
you can infer out of that the direction

840
00:30:05,430 --> 00:30:03,520
of the neutrino so in this case for

841
00:30:08,230 --> 00:30:05,440
instance for that particular detector

842
00:30:09,990 --> 00:30:08,240
you have a cone produced by

843
00:30:11,909 --> 00:30:10,000
one of these charged particles that were

844
00:30:14,389 --> 00:30:11,919
produced in a in a nutrient interaction

845
00:30:17,110 --> 00:30:14,399
and out of the as i said the the shape

846
00:30:19,830 --> 00:30:17,120
of that cone the the size and the timing

847
00:30:23,510 --> 00:30:21,830
different geometry of this detector you

848
00:30:25,830 --> 00:30:23,520
can actually calculate where that

849
00:30:28,789 --> 00:30:25,840
neutrino was coming from

850
00:30:30,950 --> 00:30:28,799
okay so that is about neutrinos but as i

851
00:30:33,190 --> 00:30:30,960
said these are neutrinos at lower

852
00:30:34,950 --> 00:30:33,200
energies in this kind of speed that we

853
00:30:38,149 --> 00:30:34,960
have these are neutrinos about a million

854
00:30:40,070 --> 00:30:38,159
times the the energy of visible light

855
00:30:42,149 --> 00:30:40,080
but we actually want to go to much

856
00:30:44,470 --> 00:30:42,159
higher energies and that is because

857
00:30:46,070 --> 00:30:44,480
that's where most of these extreme

858
00:30:47,909 --> 00:30:46,080
sources are that we want to study with

859
00:30:50,230 --> 00:30:47,919
neutrinos things like active galactic

860
00:30:51,909 --> 00:30:50,240
nuclei that are powered by supermassive

861
00:30:53,990 --> 00:30:51,919
black holes things like

862
00:30:55,909 --> 00:30:54,000
accelerators of particles that reach

863
00:30:56,950 --> 00:30:55,919

energies that we cannot reach at earth

864
00:30:58,549 --> 00:30:56,960
things like

865
00:31:00,549 --> 00:30:58,559
chaotic

866
00:31:03,110 --> 00:31:00,559
catastrophic events like a gamma-ray

867
00:31:05,669 --> 00:31:03,120
burst that lead to the either the

868
00:31:08,549 --> 00:31:05,679
explosion of the massive star or the

869
00:31:11,350 --> 00:31:08,559
merger of neutron stars all of these

870
00:31:13,909 --> 00:31:11,360
things may emit a neutrinos but at much

871
00:31:15,509 --> 00:31:13,919
higher energies and that's a very big

872
00:31:17,269 --> 00:31:15,519
challenge for neutrino astronomy because

873
00:31:19,029 --> 00:31:17,279
if it was hard to detect neutrinos at

874
00:31:20,950 --> 00:31:19,039
lower energies where you have so many of

875
00:31:23,029 --> 00:31:20,960
them like in this plot i'm showing here

876
00:31:23,830 --> 00:31:23,039
kind of the flux of neutrinos is how

877
00:31:26,149 --> 00:31:23,840
many

878
00:31:28,870 --> 00:31:26,159
neutrinos we take per uh per unit time

879
00:31:31,669 --> 00:31:28,880
at earth and you see that in on the y

880
00:31:33,909 --> 00:31:31,679
axis this very large range of numbers

881
00:31:35,350 --> 00:31:33,919
from 10 to the 13 to the 10 to the minus

882
00:31:38,149 --> 00:31:35,360
36

883
00:31:40,070 --> 00:31:38,159
means that um there are many more solar

884
00:31:41,509 --> 00:31:40,080
neutrinos than there are again neutrinos

885
00:31:42,389 --> 00:31:41,519
for instance or that we expect them to

886
00:31:46,950 --> 00:31:42,399
be

887
00:31:48,630 --> 00:31:46,960
flux for this high energy neutrinos

888
00:31:50,710 --> 00:31:48,640

above 10 to the 12 electron volt so

889
00:31:52,710 --> 00:31:50,720
about three times that of the energy of

890
00:31:54,789 --> 00:31:52,720
visible light it's about a hundred

891
00:31:57,190 --> 00:31:54,799
thousand neutrinos

892
00:31:59,669 --> 00:31:57,200
per square kilometer per year so that's

893
00:32:02,070 --> 00:31:59,679
not much actually in order to detect

894
00:32:04,710 --> 00:32:02,080
this neutrino flux you need a gigantic

895
00:32:06,470 --> 00:32:04,720
detector something that has a mass of

896
00:32:09,590 --> 00:32:06,480
about one gigaton

897
00:32:10,630 --> 00:32:09,600
so or one i mean a billion tons of

898
00:32:13,190 --> 00:32:10,640
something

899
00:32:15,909 --> 00:32:13,200
and in order to get that you need about

900
00:32:17,509 --> 00:32:15,919
a kilometer cube of water and if it was

901
00:32:19,110 --> 00:32:17,519
hard and expensive to build this

902
00:32:21,110 --> 00:32:19,120
detector in japan you can imagine how

903
00:32:24,149 --> 00:32:21,120
built and expensive it would be to to

904
00:32:25,190 --> 00:32:24,159
build a cubic kilometer of anything

905
00:32:32,230 --> 00:32:25,200
so

906
00:32:34,070 --> 00:32:32,240
those uh detectors not only to study

907
00:32:36,470 --> 00:32:34,080
these different objects that are out

908
00:32:38,149 --> 00:32:36,480
there like agn and so on but also to

909
00:32:39,909 --> 00:32:38,159
determine the origin of what we know to

910
00:32:41,830 --> 00:32:39,919
be the highest energy particles in the

911
00:32:43,430 --> 00:32:41,840
universe that we call cosmic rays in

912
00:32:44,950 --> 00:32:43,440
this case in the guess of cosmic rays

913
00:32:47,029 --> 00:32:44,960

there are charged particles so as i said

914
00:32:49,830 --> 00:32:47,039
before they don't point back to their

915
00:32:51,509 --> 00:32:49,840
source so really by figuring out if

916
00:32:53,509 --> 00:32:51,519
there are neutrinos coming from the same

917
00:32:55,110 --> 00:32:53,519
direction we can understand the origin

918
00:32:56,950 --> 00:32:55,120
of the of discussing ways of these

919
00:32:58,549 --> 00:32:56,960
charged particles we've known about them

920
00:33:00,789 --> 00:32:58,559
for over a century we haven't determined

921
00:33:03,029 --> 00:33:00,799
what the origin is but we can find them

922
00:33:04,630 --> 00:33:03,039
using neutrinos and also gamma rays

923
00:33:06,310 --> 00:33:04,640
because every time there's a cosmic ray

924
00:33:07,350 --> 00:33:06,320
that interacts with something on the way

925
00:33:09,430 --> 00:33:07,360
to earth

926
00:33:10,789 --> 00:33:09,440
that interaction will lead to neutrinos

927
00:33:13,990 --> 00:33:10,799
and photons being produced at the same

928
00:33:16,149 --> 00:33:14,000
time gamma rays and neutrinos so

929
00:33:17,750 --> 00:33:16,159
both of those particles are neutral so

930
00:33:20,230 --> 00:33:17,760
they travel on straight lines and if you

931
00:33:21,990 --> 00:33:20,240
happen to see in the sky a joint source

932
00:33:23,909 --> 00:33:22,000
of both neutrinos and gamma rays you

933
00:33:27,110 --> 00:33:23,919
have a very good guess that that could

934
00:33:29,590 --> 00:33:27,120
be a source of cosmic rays

935
00:33:31,110 --> 00:33:29,600
okay so now that we have the motivation

936
00:33:32,870 --> 00:33:31,120
why we want to build it how do we

937
00:33:34,789 --> 00:33:32,880
actually build a neutrino telescope that

938
00:33:36,070 --> 00:33:34,799

has a size of about one kilometer cube

939
00:33:37,110 --> 00:33:36,080
and that goes back to essentially the

940
00:33:39,509 --> 00:33:37,120
60s

941
00:33:42,149 --> 00:33:39,519
where markup and elsanski

942
00:33:44,310 --> 00:33:42,159
were working on um an idea for how to

943
00:33:46,789 --> 00:33:44,320
build such a detector and they proposed

944
00:33:48,470 --> 00:33:46,799
to do it on a natural body of water okay

945
00:33:50,070 --> 00:33:48,480
instead of building a gigantic pool that

946
00:33:51,990 --> 00:33:50,080
has a size of one kilometer cube which

947
00:33:55,029 --> 00:33:52,000
will be extremely expensive to build you

948
00:33:57,830 --> 00:33:55,039
can actually use a very deep lake or

949
00:33:59,430 --> 00:33:57,840
eyes and then put detectors there so you

950
00:34:00,789 --> 00:33:59,440
can actually see that light the change

951
00:34:02,549 --> 00:34:00,799
of light produced by the interaction of

952
00:34:05,350 --> 00:34:02,559
the neutrinos

953
00:34:07,509 --> 00:34:05,360
so as i said large target masses can can

954
00:34:09,430 --> 00:34:07,519
be found in natural bodies of water and

955
00:34:10,869 --> 00:34:09,440
that's those proposed already in the in

956
00:34:12,950 --> 00:34:10,879
the 1960s

957
00:34:14,710 --> 00:34:12,960
so these high-energy neutrino telescopes

958
00:34:17,109 --> 00:34:14,720
the one that detects that are aimed to

959
00:34:19,109 --> 00:34:17,119
detect energies from agn

960
00:34:20,629 --> 00:34:19,119
grps and so on

961
00:34:23,270 --> 00:34:20,639
use this principle

962
00:34:25,109 --> 00:34:23,280
instead of having kind of a container a

963
00:34:27,990 --> 00:34:25,119

cylinder with

964
00:34:28,950 --> 00:34:28,000
walls made of or surrounded by light

965
00:34:32,629 --> 00:34:28,960
sensors

966
00:34:34,710 --> 00:34:32,639
array so they're kind of a

967
00:34:37,030 --> 00:34:34,720
three-dimensional sensor so every time

968
00:34:38,470 --> 00:34:37,040
you have a neutrino uh interact you will

969
00:34:40,790 --> 00:34:38,480
produce a charged particle for instance

970
00:34:41,909 --> 00:34:40,800
a muon like you can see here that muon

971
00:34:43,669 --> 00:34:41,919
will travel through this

972
00:34:45,349 --> 00:34:43,679
three-dimensional array of light sensors

973
00:34:46,710 --> 00:34:45,359
producing drink of light

974
00:34:48,629 --> 00:34:46,720
and out of that light you can actually

975
00:34:49,909 --> 00:34:48,639
figure out where the immune was coming

976
00:34:52,069 --> 00:34:49,919
from and therefore infer where the

977
00:34:55,190 --> 00:34:52,079
neutrino was coming from

978
00:34:57,270 --> 00:34:55,200
okay so we need just a large body of

979
00:34:58,790 --> 00:34:57,280
water or eyes that can be intro

980
00:35:00,230 --> 00:34:58,800
instrumented with the sensitive light

981
00:35:02,230 --> 00:35:00,240
sensors

982
00:35:04,230 --> 00:35:02,240
and the good thing is that uh muons can

983
00:35:06,150 --> 00:35:04,240
travel actually for very long distances

984
00:35:08,550 --> 00:35:06,160
from something between 50 meters to over

985
00:35:10,870 --> 00:35:08,560
50 kilometers depending on their energy

986
00:35:12,710 --> 00:35:10,880
so even neutrinos that interact far away

987
00:35:15,510 --> 00:35:12,720
from our sensors they can reach the they

988
00:35:17,190 --> 00:35:15,520

can still reach the detector and uh

989
00:35:18,470 --> 00:35:17,200
provide a much larger volume with which

990
00:35:20,150 --> 00:35:18,480
to detect them

991
00:35:22,230 --> 00:35:20,160
so the main options for the playing

992
00:35:23,589 --> 00:35:22,240
these neutrino detectors are really deep

993
00:35:26,550 --> 00:35:23,599
glacial eyes

994
00:35:27,750 --> 00:35:26,560
or legs deep legs or deep or the deep

995
00:35:29,430 --> 00:35:27,760
sea

996
00:35:31,270 --> 00:35:29,440
so the current generation of telescopes

997
00:35:33,829 --> 00:35:31,280
actually uses this principle

998
00:35:36,069 --> 00:35:33,839
uh we have three uh one of the actually

999
00:35:38,550 --> 00:35:36,079
was deactivated very soon very very very

1000
00:35:41,750 --> 00:35:38,560
recently there's one uh called baikal

1001
00:35:44,550 --> 00:35:41,760
dvd it's one of in the deepest lake uh

1002
00:35:46,630 --> 00:35:44,560
in the world like by calling russia

1003
00:35:49,109 --> 00:35:46,640
it has already reached about a third of

1004
00:35:50,790 --> 00:35:49,119
the kilometer cube that is needed to

1005
00:35:52,790 --> 00:35:50,800
build a working neutrino telescope that

1006
00:35:54,950 --> 00:35:52,800
is supposed to see these things

1007
00:35:56,390 --> 00:35:54,960
and until very recently we actually have

1008
00:35:58,150 --> 00:35:56,400
one in the mediterranean sea called

1009
00:35:59,670 --> 00:35:58,160
antares

1010
00:36:02,790 --> 00:35:59,680
but it's very very small it's about a

1011
00:36:04,710 --> 00:36:02,800
100th of a kilometer cube

1012
00:36:06,550 --> 00:36:04,720
and finally i want to talk more about

1013
00:36:07,990 --> 00:36:06,560

ice cube because ice cube is the one of

1014
00:36:09,829 --> 00:36:08,000
four first of all is the one i'm

1015
00:36:12,230 --> 00:36:09,839
involved with but also is the one the

1016
00:36:13,829 --> 00:36:12,240
first one to reach one kilometer cube in

1017
00:36:16,230 --> 00:36:13,839
size which is the target mass that you

1018
00:36:18,790 --> 00:36:16,240
need to do nutrients from it with it's

1019
00:36:21,349 --> 00:36:18,800
composed of more than 5000 sensors

1020
00:36:23,910 --> 00:36:21,359
deployed over as i said one kilometer

1021
00:36:25,349 --> 00:36:23,920
cube of ice at the south pole and the

1022
00:36:27,829 --> 00:36:25,359
construction

1023
00:36:28,950 --> 00:36:27,839
finished in 20 in 2010.

1024
00:36:30,870 --> 00:36:28,960
so this is the one i'm going to be

1025
00:36:33,190 --> 00:36:30,880
talking about more it's not only the one

1026
00:36:35,270 --> 00:36:33,200
that is fully built and operational but

1027
00:36:37,430 --> 00:36:35,280
also the most sensitive one

1028
00:36:39,109 --> 00:36:37,440
so this is the softball and you cannot

1029
00:36:40,470 --> 00:36:39,119
see the neutrino telescope anywhere here

1030
00:36:42,870 --> 00:36:40,480
because actually the neutrino telescope

1031
00:36:44,790 --> 00:36:42,880
is buried in the glacier at the south

1032
00:36:46,710 --> 00:36:44,800
pole and the good thing about the deep

1033
00:36:49,030 --> 00:36:46,720
antarctic ice is that it's very abundant

1034
00:36:51,190 --> 00:36:49,040
there is everywhere ice and hope we can

1035
00:36:54,069 --> 00:36:51,200
keep that ice for a long time it's very

1036
00:36:56,150 --> 00:36:54,079
transparent we cannot even make ice in

1037
00:36:57,670 --> 00:36:56,160
the in the lab that is so transparent as

1038
00:36:59,349 --> 00:36:57,680

transparent as the

1039
00:37:01,910 --> 00:36:59,359
deep eyes of the south pole and it's

1040
00:37:04,069 --> 00:37:01,920
very dark so the light that you see in

1041
00:37:05,829 --> 00:37:04,079
the deep ice of the south pole is mostly

1042
00:37:07,990 --> 00:37:05,839
coming from this cosmic particles which

1043
00:37:09,430 --> 00:37:08,000
is pretty amazing

1044
00:37:11,109 --> 00:37:09,440
so this is the ice cube neutrino

1045
00:37:12,310 --> 00:37:11,119
telescope we have here our web page if

1046
00:37:14,630 --> 00:37:12,320
you want to visit it and as i said

1047
00:37:16,390 --> 00:37:14,640
before it's composed of more than five

1048
00:37:18,630 --> 00:37:16,400
thousands of these sensors that have a

1049
00:37:21,349 --> 00:37:18,640
kind of a glass pressure sphere so the

1050
00:37:22,870 --> 00:37:21,359
ice doesn't get into the light sensor

1051
00:37:24,790 --> 00:37:22,880
and here on top you have this little

1052
00:37:26,310 --> 00:37:24,800
building that you may see in this

1053
00:37:28,390 --> 00:37:26,320
picture here

1054
00:37:30,550 --> 00:37:28,400
and that is where we host uh the house

1055
00:37:32,390 --> 00:37:30,560
the computers all this uh information

1056
00:37:34,870 --> 00:37:32,400
coming from these light sensors goes up

1057
00:37:37,430 --> 00:37:34,880
to the surface via these cables and then

1058
00:37:39,670 --> 00:37:37,440
travels to the computers that are uh

1059
00:37:40,710 --> 00:37:39,680
housed there in this um in this little

1060
00:37:42,230 --> 00:37:40,720
building

1061
00:37:44,470 --> 00:37:42,240
so as i said it's the first kilometer

1062
00:37:46,950 --> 00:37:44,480
cube nutrition telescope more than 5000

1063
00:37:48,950 --> 00:37:46,960

sensors deployed at depths between one

1064
00:37:50,630 --> 00:37:48,960
and a half and two and a half kilometers

1065
00:37:52,870 --> 00:37:50,640
so really the top part of ice cube

1066
00:37:56,069 --> 00:37:52,880
starts almost almost a deep

1067
00:37:57,510 --> 00:37:56,079
uh a mile deep into the ice and it goes

1068
00:37:59,430 --> 00:37:57,520
all the way up to almost three

1069
00:38:01,349 --> 00:37:59,440
kilometers in depth

1070
00:38:04,150 --> 00:38:01,359
uh its construction as i said finished

1071
00:38:05,750 --> 00:38:04,160
in december of 2011 in 2010 and it has

1072
00:38:07,430 --> 00:38:05,760
other components that are dedicated to

1073
00:38:08,790 --> 00:38:07,440
other studies of cosmic rays actually

1074
00:38:10,390 --> 00:38:08,800
and lower energy

1075
00:38:13,910 --> 00:38:10,400
neutrinos

1076
00:38:16,390 --> 00:38:13,920
so the construction started in uh the

1077
00:38:19,670 --> 00:38:16,400
summer of the austral summer of the

1078
00:38:21,750 --> 00:38:19,680
southern summer of 20 2004 2005 with the

1079
00:38:24,950 --> 00:38:21,760
deployment of one of these

1080
00:38:27,750 --> 00:38:24,960
long strings of sensors that each one of

1081
00:38:29,510 --> 00:38:27,760
them has 66 sensors attached to it and

1082
00:38:31,030 --> 00:38:29,520
then because this is working at the

1083
00:38:33,349 --> 00:38:31,040
south pole you can only build during the

1084
00:38:34,870 --> 00:38:33,359
summer there which is still very very

1085
00:38:37,030 --> 00:38:34,880
cold

1086
00:38:38,710 --> 00:38:37,040
so over the next seasons ice cube

1087
00:38:40,790 --> 00:38:38,720
started growing and growing and while it

1088
00:38:41,510 --> 00:38:40,800

was growing it was actually taking data

1089
00:38:43,750 --> 00:38:41,520
so

1090
00:38:45,990 --> 00:38:43,760
here started with one string one cable

1091
00:38:50,150 --> 00:38:46,000
filled with sensors then upgraded to

1092
00:38:52,710 --> 00:38:50,160
nine strings 22 strings four strings 59

1093
00:38:55,670 --> 00:38:52,720
79 and finally 86 strings which was the

1094
00:38:57,750 --> 00:38:55,680
completion of the full detector in the

1095
00:38:59,589 --> 00:38:57,760
in december of 2010.

1096
00:39:01,910 --> 00:38:59,599
so this how it looks when you're

1097
00:39:04,630 --> 00:39:01,920
deploying the sensors

1098
00:39:06,310 --> 00:39:04,640
this hole goes as i said almost two and

1099
00:39:08,870 --> 00:39:06,320
a half kilometers deep into the ice at

1100
00:39:10,550 --> 00:39:08,880
some point it actually reaches water

1101
00:39:12,230 --> 00:39:10,560
and what you see here is the cable that

1102
00:39:14,630 --> 00:39:12,240
brings the data from this light sensors

1103
00:39:16,870 --> 00:39:14,640
to the surface and one of the sensors

1104
00:39:18,710 --> 00:39:16,880
kind of you can see here illuminated so

1105
00:39:20,390 --> 00:39:18,720
how do you actually build such a big

1106
00:39:22,069 --> 00:39:20,400
detector uh

1107
00:39:24,310 --> 00:39:22,079
in the eyes i mean you you will have to

1108
00:39:25,990 --> 00:39:24,320
drill some holes into the eyes to deploy

1109
00:39:28,069 --> 00:39:26,000
these long cables

1110
00:39:29,829 --> 00:39:28,079
and you will think that it is very

1111
00:39:31,270 --> 00:39:29,839
complicated but i mean it's pretty

1112
00:39:32,870 --> 00:39:31,280
straightforward of course it's very

1113
00:39:35,750 --> 00:39:32,880

expensive to build it but still it's

1114
00:39:38,470 --> 00:39:35,760
break straightforward idea you just put

1115
00:39:41,270 --> 00:39:38,480
a long hose with hot water and you just

1116
00:39:42,950 --> 00:39:41,280
point it down and the hose will just

1117
00:39:45,910 --> 00:39:42,960
drill a hole

1118
00:39:47,990 --> 00:39:45,920
through through the ice you first

1119
00:39:50,150 --> 00:39:48,000
kind of try to melt the top part which

1120
00:39:51,589 --> 00:39:50,160
is mostly compacted snow

1121
00:39:53,750 --> 00:39:51,599
you take that out

1122
00:39:56,150 --> 00:39:53,760
and then you replace that

1123
00:39:59,430 --> 00:39:56,160
serpentine with this long hose with a

1124
00:40:01,030 --> 00:39:59,440
high pressure water that drills

1125
00:40:03,109 --> 00:40:01,040
all the way down to

1126
00:40:05,109 --> 00:40:03,119
two and a half almost between two and a

1127
00:40:06,390 --> 00:40:05,119
half and almost three kilometers deep

1128
00:40:08,309 --> 00:40:06,400
once you have done that you have to do

1129
00:40:10,390 --> 00:40:08,319
this very quickly because the

1130
00:40:13,190 --> 00:40:10,400
water will freeze again in place

1131
00:40:15,589 --> 00:40:13,200
you take out that hose and you put in

1132
00:40:17,270 --> 00:40:15,599
your cable with light sensors and once

1133
00:40:19,670 --> 00:40:17,280
you've done that the sensors will be

1134
00:40:21,670 --> 00:40:19,680
frozen in place essentially forever

1135
00:40:22,710 --> 00:40:21,680
hopefully forever

1136
00:40:24,630 --> 00:40:22,720
so

1137
00:40:27,109 --> 00:40:24,640
once you've done that 86 times you have

1138
00:40:28,870 --> 00:40:27,119

yourself a nice neutrino telescope and

1139
00:40:31,190 --> 00:40:28,880
this kind of some pictures of how the

1140
00:40:33,030 --> 00:40:31,200
drilling stations looked the south pole

1141
00:40:34,710 --> 00:40:33,040
at the time and kind of the the

1142
00:40:37,670 --> 00:40:34,720
deployment of the cables that bring the

1143
00:40:39,910 --> 00:40:37,680
data uh from the sensors to

1144
00:40:41,829 --> 00:40:39,920
the computer center that we have there

1145
00:40:43,750 --> 00:40:41,839
at the ice cube lab

1146
00:40:46,230 --> 00:40:43,760
so this is in the end ice cube this is

1147
00:40:49,030 --> 00:40:46,240
how it's been built and as i start the

1148
00:40:50,950 --> 00:40:49,040
depths at which this things are located

1149
00:40:54,150 --> 00:40:50,960
these sensors are located

1150
00:40:55,670 --> 00:40:54,160
so how does ice cube see neutrinos so

1151
00:40:57,910 --> 00:40:55,680
as i said we don't see the neutrinos

1152
00:41:00,069 --> 00:40:57,920
directly we see

1153
00:41:02,230 --> 00:41:00,079
the light the chunk of light produced by

1154
00:41:04,470 --> 00:41:02,240
charged particles that are produced in

1155
00:41:06,309 --> 00:41:04,480
the interaction of the neutrinos so we

1156
00:41:08,710 --> 00:41:06,319
typically have two different types of

1157
00:41:10,710 --> 00:41:08,720
event topologies or shapes of

1158
00:41:11,829 --> 00:41:10,720
of events that are produced by nutrient

1159
00:41:13,990 --> 00:41:11,839
interactions

1160
00:41:15,589 --> 00:41:14,000
the first one is this one the muon the

1161
00:41:16,870 --> 00:41:15,599
neon track

1162
00:41:19,270 --> 00:41:16,880
so you see here that it's kind of an

1163
00:41:21,750 --> 00:41:19,280

elongated shape and that each one of

1164
00:41:24,550 --> 00:41:21,760
these dots is one detector of those

1165
00:41:27,510 --> 00:41:24,560
strings that saw a little bit of light

1166
00:41:30,069 --> 00:41:27,520
okay the size of each one of these dots

1167
00:41:32,790 --> 00:41:30,079
indicates how much light it was seen and

1168
00:41:35,190 --> 00:41:32,800
the color indicates the time red means

1169
00:41:36,710 --> 00:41:35,200
early and blue means late that meant

1170
00:41:38,630 --> 00:41:36,720
that that means that there was a charged

1171
00:41:40,230 --> 00:41:38,640
particle a muon in this case that

1172
00:41:42,790 --> 00:41:40,240
entered the detector through the left

1173
00:41:44,470 --> 00:41:42,800
here and emerged kind of somewhere

1174
00:41:46,309 --> 00:41:44,480
up and to the right

1175
00:41:49,030 --> 00:41:46,319
towards the blue blue end of that

1176
00:41:50,390 --> 00:41:49,040
elongated shape and since you have that

1177
00:41:52,150 --> 00:41:50,400
kind of elongated shape you can actually

1178
00:41:53,750 --> 00:41:52,160
reconstruct where that neutrino and

1179
00:41:56,309 --> 00:41:53,760
where the muon was coming from in the

1180
00:41:58,150 --> 00:41:56,319
sky and that's the kind of the the most

1181
00:41:59,510 --> 00:41:58,160
important thing to do astronomy you want

1182
00:42:00,790 --> 00:41:59,520
to reconstruct where the neutrinos are

1183
00:42:02,950 --> 00:42:00,800
coming from in the sky so you can put

1184
00:42:04,550 --> 00:42:02,960
them in the sky map and figure out what

1185
00:42:07,750 --> 00:42:04,560
their what's there

1186
00:42:09,430 --> 00:42:07,760
you also have other types of neutrinos

1187
00:42:11,750 --> 00:42:09,440
that through their interaction could

1188
00:42:12,790 --> 00:42:11,760

produce what we call cascades they're

1189
00:42:15,109 --> 00:42:12,800
mostly

1190
00:42:16,790 --> 00:42:15,119
almost aesthetically

1191
00:42:18,390 --> 00:42:16,800
and you can see that this is not

1192
00:42:20,390 --> 00:42:18,400
particularly pointing in any particular

1193
00:42:21,990 --> 00:42:20,400
direction but if you apply advanced

1194
00:42:23,510 --> 00:42:22,000
reconstructions to this kind of events

1195
00:42:25,910 --> 00:42:23,520
you can still get

1196
00:42:27,670 --> 00:42:25,920
almost 15 degrees angular solution i

1197
00:42:29,670 --> 00:42:27,680
mean to do astronomy this is terrible as

1198
00:42:31,430 --> 00:42:29,680
you can imagine you were used to arc

1199
00:42:33,190 --> 00:42:31,440
seconds or even less than arc seconds

1200
00:42:35,190 --> 00:42:33,200
with hubble and with ground-based

1201
00:42:37,190 --> 00:42:35,200
telescopes and we're thinking that for

1202
00:42:38,950 --> 00:42:37,200
us for neutrino telescopes

1203
00:42:42,230 --> 00:42:38,960
let's say a 0.1

1204
00:42:45,589 --> 00:42:42,240
degree angular solution is fantastic

1205
00:42:47,510 --> 00:42:45,599
if you go outside on a on a moon

1206
00:42:49,910 --> 00:42:47,520
on a night when the moon is up

1207
00:42:51,030 --> 00:42:49,920
um the size of the moon is about half a

1208
00:42:52,870 --> 00:42:51,040
degree

1209
00:42:54,309 --> 00:42:52,880
so that's about our angular resolution

1210
00:42:56,390 --> 00:42:54,319
and that is the good angle resolution

1211
00:42:58,230 --> 00:42:56,400
for neutrino telescope the fact that you

1212
00:43:00,630 --> 00:42:58,240
can see in the face of the moon you can

1213
00:43:02,390 --> 00:43:00,640

see little patches of dark stuff that

1214
00:43:03,589 --> 00:43:02,400
means that your eyes have better angle

1215
00:43:05,670 --> 00:43:03,599
resolution

1216
00:43:07,030 --> 00:43:05,680
to the sky that ice cube does in

1217
00:43:08,710 --> 00:43:07,040
neutrinos of course you can see only

1218
00:43:09,750 --> 00:43:08,720
light and ice keeps these neutrinos but

1219
00:43:11,589 --> 00:43:09,760
still

1220
00:43:12,870 --> 00:43:11,599
we're working hard to improve this

1221
00:43:15,910 --> 00:43:12,880
angular resolution because it's one of

1222
00:43:17,270 --> 00:43:15,920
the key ingredients in doing astronomy

1223
00:43:18,950 --> 00:43:17,280
so here let me show you kind of a

1224
00:43:21,109 --> 00:43:18,960
candidate neutrino event this was an

1225
00:43:22,630 --> 00:43:21,119
actual recorded event and what you'll

1226
00:43:24,710 --> 00:43:22,640
see here is kind of a reconstruction

1227
00:43:27,109 --> 00:43:24,720
this line that you see coming from the

1228
00:43:28,870 --> 00:43:27,119
from the top left is the reconstructed

1229
00:43:31,750 --> 00:43:28,880
direction of the neutrino and as it

1230
00:43:34,390 --> 00:43:31,760
enters the neutrino the telescope you'll

1231
00:43:36,390 --> 00:43:34,400
see that it leaves traces of light

1232
00:43:38,630 --> 00:43:36,400
behind the kind of the blue bubble there

1233
00:43:40,390 --> 00:43:38,640
is also a kind of an animation showing

1234
00:43:42,150 --> 00:43:40,400
where the chunk of light was produced

1235
00:43:44,150 --> 00:43:42,160
but in general you see that

1236
00:43:45,750 --> 00:43:44,160
kind of that elongated shape again and

1237
00:43:47,670 --> 00:43:45,760
therefore that allows us to reconstruct

1238
00:43:49,430 --> 00:43:47,680

where that neutrino was coming from

1239
00:43:52,150 --> 00:43:49,440
originally

1240
00:43:53,750 --> 00:43:52,160
okay so what do we need to do between

1241
00:43:55,750 --> 00:43:53,760
astronomy

1242
00:43:57,270 --> 00:43:55,760
first we need to find cosmic neutrinos

1243
00:43:58,710 --> 00:43:57,280
and say as you will show you it's not

1244
00:44:00,309 --> 00:43:58,720
that easy

1245
00:44:01,990 --> 00:44:00,319
and then we need many of these cosmic

1246
00:44:03,589 --> 00:44:02,000
neutrinos because you want plenty of

1247
00:44:05,510 --> 00:44:03,599
them so that you can put them on the map

1248
00:44:07,190 --> 00:44:05,520
and figure out where they're coming from

1249
00:44:09,910 --> 00:44:07,200
that means that since we don't have a

1250
00:44:11,430 --> 00:44:09,920
control over uh how many neutrinos the

1251
00:44:13,190 --> 00:44:11,440
sources can produce the only thing we

1252
00:44:15,190 --> 00:44:13,200
can do is make bigger and bigger

1253
00:44:16,630 --> 00:44:15,200
telescopes that can give us more and

1254
00:44:17,670 --> 00:44:16,640
more neutrinos

1255
00:44:19,270 --> 00:44:17,680
the other thing is that we need good

1256
00:44:20,870 --> 00:44:19,280
angular resolution and we also want

1257
00:44:22,309 --> 00:44:20,880
energy resolution for the energies of

1258
00:44:23,589 --> 00:44:22,319
the transport this neutrinos i won't

1259
00:44:24,950 --> 00:44:23,599
talk too much about it so i want to

1260
00:44:27,750 --> 00:44:24,960
concentrate just on good angle

1261
00:44:29,430 --> 00:44:27,760
resolution and we also want to do these

1262
00:44:31,190 --> 00:44:29,440
measurements in low backgrounds which

1263
00:44:32,790 --> 00:44:31,200

means that we can separate the neutrinos

1264
00:44:34,230 --> 00:44:32,800
that are actually there from everything

1265
00:44:37,270 --> 00:44:34,240
else that looks like a neutrino but it's

1266
00:44:38,630 --> 00:44:37,280
not really a neutrino okay so why is it

1267
00:44:40,150 --> 00:44:38,640
so hard to find this astrophysical

1268
00:44:43,190 --> 00:44:40,160
neutrinos that are produced somewhere in

1269
00:44:46,470 --> 00:44:43,200
the universe it's because we we do that

1270
00:44:49,190 --> 00:44:46,480
search on a background dominated um

1271
00:44:51,990 --> 00:44:49,200
on a i mean on on a background-dominated

1272
00:44:54,309 --> 00:44:52,000
case we have let's say ice cube is at

1273
00:44:55,750 --> 00:44:54,319
the softball so i've flipped around the

1274
00:44:57,829 --> 00:44:55,760
the globe i mean as a southern

1275
00:45:00,150 --> 00:44:57,839
hemisphere and myself this is how i view

1276
00:45:01,589 --> 00:45:00,160
the world anyway so you have ice cube

1277
00:45:03,510 --> 00:45:01,599
here if of course not the scale will

1278
00:45:05,030 --> 00:45:03,520
wish to have ice cubes be as big as a

1279
00:45:05,750 --> 00:45:05,040
good chunk of the earth

1280
00:45:06,710 --> 00:45:05,760
but

1281
00:45:13,109 --> 00:45:06,720
the

1282
00:45:15,109 --> 00:45:13,119
south pole are actually produced by

1283
00:45:17,109 --> 00:45:15,119
coastal grays that hit the atmosphere

1284
00:45:18,710 --> 00:45:17,119
and produce these muons these meals are

1285
00:45:20,230 --> 00:45:18,720
not being produced by neutrinos they're

1286
00:45:22,069 --> 00:45:20,240
just produced by cosmic rays that

1287
00:45:23,670 --> 00:45:22,079
interact with the atmosphere but they

1288
00:45:25,510 --> 00:45:23,680

look a lot like a neutrino there are

1289
00:45:27,190 --> 00:45:25,520
still muons going through our detector

1290
00:45:29,190 --> 00:45:27,200
and there's also a signature of neutrino

1291
00:45:31,910 --> 00:45:29,200
detections

1292
00:45:33,750 --> 00:45:31,920
okay so that's downgoing muons that can

1293
00:45:34,790 --> 00:45:33,760
travel through your detector

1294
00:45:36,390 --> 00:45:34,800
um

1295
00:45:37,829 --> 00:45:36,400
then the other thing is that since

1296
00:45:39,750 --> 00:45:37,839
neutrinos can go through everything they

1297
00:45:42,470 --> 00:45:39,760
can also go through our planet so even

1298
00:45:44,470 --> 00:45:42,480
neutrinos coming from also acoustic gray

1299
00:45:46,790 --> 00:45:44,480
interactions but on the other side of

1300
00:45:49,430 --> 00:45:46,800
the planet can still reach ice cube and

1301
00:45:51,510 --> 00:45:49,440
pretend to be an astrophysical neutrino

1302
00:45:53,109 --> 00:45:51,520
so we want to remove both the gossip

1303
00:45:55,750 --> 00:45:53,119
waste

1304
00:45:58,069 --> 00:45:55,760
cosmic ray muons that are fake i mean

1305
00:45:59,510 --> 00:45:58,079
that pass as a neutrino and also the

1306
00:46:01,190 --> 00:45:59,520
atmospheric neutrinos that are also

1307
00:46:02,710 --> 00:46:01,200
produced by cosmic rays but are not

1308
00:46:05,670 --> 00:46:02,720
really produced by

1309
00:46:07,589 --> 00:46:05,680
direct astrophysical sources

1310
00:46:09,030 --> 00:46:07,599
and finally we have every now and then

1311
00:46:10,470 --> 00:46:09,040
we'll have an astrophysical neutrinos

1312
00:46:12,230 --> 00:46:10,480
coming directly from one of the sources

1313
00:46:14,309 --> 00:46:12,240

that we want to study so what is the

1314
00:46:17,109 --> 00:46:14,319
challenge here how big is that challenge

1315
00:46:18,790 --> 00:46:17,119
we detect about three thousand muons per

1316
00:46:20,470 --> 00:46:18,800
second in ice cube

1317
00:46:23,109 --> 00:46:20,480
and we detect about a hundred

1318
00:46:24,470 --> 00:46:23,119
atmospheric neutrinos per day none of

1319
00:46:25,670 --> 00:46:24,480
those things are the main ones that we

1320
00:46:28,470 --> 00:46:25,680
want to study to astronomy with

1321
00:46:31,190 --> 00:46:28,480
neutrinos we want to get rid of them

1322
00:46:33,270 --> 00:46:31,200
but we only detect about one neutrino

1323
00:46:35,829 --> 00:46:33,280
per month that we think is astrophysical

1324
00:46:38,069 --> 00:46:35,839
in origin that means that we have to for

1325
00:46:40,230 --> 00:46:38,079
every astrophysical neutrino that we

1326
00:46:42,950 --> 00:46:40,240
have in our data we have to throw away

1327
00:46:45,190 --> 00:46:42,960
about 10 billion things that look

1328
00:46:47,510 --> 00:46:45,200
exactly like a neutrino so it's a very

1329
00:46:48,950 --> 00:46:47,520
challenging thing to do okay

1330
00:46:50,630 --> 00:46:48,960
but the first indication that we

1331
00:46:54,630 --> 00:46:50,640
actually have astrophysical neutrinos in

1332
00:46:56,390 --> 00:46:54,640
our data came in 2013 when we identified

1333
00:46:58,069 --> 00:46:56,400
these two events that were named ernie

1334
00:47:00,790 --> 00:46:58,079
and berta so you can obviously see i

1335
00:47:02,470 --> 00:47:00,800
mean they exactly resemble the muppets

1336
00:47:04,150 --> 00:47:02,480
that are associated with them

1337
00:47:05,990 --> 00:47:04,160
not really but still

1338
00:47:07,589 --> 00:47:06,000

how do we know or how why do we think

1339
00:47:09,349 --> 00:47:07,599
that these are astrophysical neutrinos

1340
00:47:12,710 --> 00:47:09,359
is because they have a very high energy

1341
00:47:14,309 --> 00:47:12,720
of about 1 pv 10 to the 15

1342
00:47:16,069 --> 00:47:14,319
electron volts which also means 10 to

1343
00:47:17,510 --> 00:47:16,079
the 15 times

1344
00:47:19,910 --> 00:47:17,520
about a

1345
00:47:22,390 --> 00:47:19,920
10 trillion sorry a thousand trillion

1346
00:47:24,549 --> 00:47:22,400
times the energy of visible light so

1347
00:47:26,549 --> 00:47:24,559
we're way out there things that we will

1348
00:47:28,710 --> 00:47:26,559
be very hard to see

1349
00:47:31,510 --> 00:47:28,720
with gamma rays almost impossible to see

1350
00:47:32,950 --> 00:47:31,520
from very far uh sources

1351
00:47:35,030 --> 00:47:32,960
so why do we think that these are so

1352
00:47:36,630 --> 00:47:35,040
physical is because these atmospheric

1353
00:47:38,870 --> 00:47:36,640
neutrinos that are produced in cosmic

1354
00:47:41,109 --> 00:47:38,880
ray interactions in the earth

1355
00:47:43,510 --> 00:47:41,119
only reach to so high energies they

1356
00:47:45,670 --> 00:47:43,520
don't go that far in terms of energy so

1357
00:47:47,349 --> 00:47:45,680
if you see a very high energy neutrino

1358
00:47:49,109 --> 00:47:47,359
there is likely to be astrophysical

1359
00:47:50,710 --> 00:47:49,119
energy because the gossip grades hitting

1360
00:47:52,230 --> 00:47:50,720
in our atmosphere cannot create that

1361
00:47:53,349 --> 00:47:52,240
okay so that was the first evidence that

1362
00:47:55,190 --> 00:47:53,359
we have

1363
00:47:57,030 --> 00:47:55,200

astrophysical neutrinos in our data

1364
00:47:59,910 --> 00:47:57,040
since this was found

1365
00:48:01,750 --> 00:47:59,920
the there was a a question immediately

1366
00:48:04,630 --> 00:48:01,760
are there more in data that we haven't

1367
00:48:05,589 --> 00:48:04,640
seen so how can we find neutrinos in our

1368
00:48:07,190 --> 00:48:05,599
data

1369
00:48:08,630 --> 00:48:07,200
throwing away everything else that looks

1370
00:48:09,910 --> 00:48:08,640
like an arduino

1371
00:48:12,630 --> 00:48:09,920
so this is how

1372
00:48:14,069 --> 00:48:12,640
a veto works and this is how this this

1373
00:48:16,790 --> 00:48:14,079
detection happened

1374
00:48:18,230 --> 00:48:16,800
let's say that you have a muon immune is

1375
00:48:20,150 --> 00:48:18,240
producing shrink of light as i mentioned

1376
00:48:22,470 --> 00:48:20,160
before and as it travels through the ice

1377
00:48:23,510 --> 00:48:22,480
cube detector it's always emitting light

1378
00:48:24,710 --> 00:48:23,520
okay

1379
00:48:27,109 --> 00:48:24,720
so

1380
00:48:29,109 --> 00:48:27,119
we define a kind of a boundary around

1381
00:48:30,870 --> 00:48:29,119
our detector made of other parts of the

1382
00:48:32,549 --> 00:48:30,880
detector so detector itself we define

1383
00:48:35,829 --> 00:48:32,559
parts of the detector to be what we call

1384
00:48:37,510 --> 00:48:35,839
a veto so if anything

1385
00:48:39,670 --> 00:48:37,520
that goes through our detector also

1386
00:48:41,829 --> 00:48:39,680
deposit light deposits light in the

1387
00:48:43,589 --> 00:48:41,839
vital region we throw that away because

1388
00:48:46,950 --> 00:48:43,599

we think that that is immune that came

1389
00:48:48,870 --> 00:48:46,960
from above or from below even

1390
00:48:51,030 --> 00:48:48,880
but that is most likely produced by just

1391
00:48:52,950 --> 00:48:51,040
a neuron and not a neutrino

1392
00:48:54,390 --> 00:48:52,960
now neutrinos can go through everything

1393
00:48:56,230 --> 00:48:54,400
and they can also interact within our

1394
00:48:57,190 --> 00:48:56,240
own detector sneaking in through the

1395
00:48:58,470 --> 00:48:57,200
veto and

1396
00:48:59,910 --> 00:48:58,480
producing a pharyngeal interaction

1397
00:49:01,510 --> 00:48:59,920
within our veto

1398
00:49:03,589 --> 00:49:01,520
and that's how we actually select it for

1399
00:49:05,670 --> 00:49:03,599
these neutrinos because these neutrinos

1400
00:49:07,109 --> 00:49:05,680
will come in and they will first

1401
00:49:08,950 --> 00:49:07,119
interact in the eyes and then you'll see

1402
00:49:10,470 --> 00:49:08,960
a muon suddenly appearing in the middle

1403
00:49:11,750 --> 00:49:10,480
of your detector and the only way that

1404
00:49:13,430 --> 00:49:11,760
you can explain that is actually if your

1405
00:49:15,109 --> 00:49:13,440
neutrino came there

1406
00:49:16,630 --> 00:49:15,119
so now you can identify neutrinos you

1407
00:49:18,069 --> 00:49:16,640
can throw away all the muons and now if

1408
00:49:20,549 --> 00:49:18,079
you require that the nutrients have

1409
00:49:22,390 --> 00:49:20,559
enough high energy to

1410
00:49:23,349 --> 00:49:22,400
kind of remove the atmospheric neutrinos

1411
00:49:25,430 --> 00:49:23,359
you can

1412
00:49:27,430 --> 00:49:25,440
pretty sure be pretty sure that you're

1413
00:49:29,270 --> 00:49:27,440

talking about astrophysical neutrinos so

1414
00:49:30,950 --> 00:49:29,280
this is what it looked like you have all

1415
00:49:32,150 --> 00:49:30,960
these red points i mean this is kind of

1416
00:49:33,990 --> 00:49:32,160
complicated access you have three

1417
00:49:36,470 --> 00:49:34,000
dimensional axis you have how many

1418
00:49:38,549 --> 00:49:36,480
events you detect on the z-axis

1419
00:49:41,109 --> 00:49:38,559
the total charge of the event which is

1420
00:49:43,430 --> 00:49:41,119
indicator of the energy of the of the of

1421
00:49:45,589 --> 00:49:43,440
the event in kind of the x-axis and

1422
00:49:48,790 --> 00:49:45,599
along the y-axis you have how much light

1423
00:49:50,950 --> 00:49:48,800
they deposited in the veto region

1424
00:49:52,790 --> 00:49:50,960
and you can see that i mean it's kind of

1425
00:49:54,230 --> 00:49:52,800
hard to see but if you follow kind of

1426
00:49:55,589 --> 00:49:54,240
this evolution of this kind of

1427
00:49:56,870 --> 00:49:55,599
three-dimensional surface you see that

1428
00:49:58,790 --> 00:49:56,880
the three-dimensional surface has a

1429
00:50:00,790 --> 00:49:58,800
pretty stable shape

1430
00:50:04,150 --> 00:50:00,800
all the way up to here

1431
00:50:06,309 --> 00:50:04,160
where you have many high energy events

1432
00:50:08,309 --> 00:50:06,319
that have high energy because they saw a

1433
00:50:10,150 --> 00:50:08,319
lot of light in the detector and also

1434
00:50:11,990 --> 00:50:10,160
they don't produce any

1435
00:50:14,630 --> 00:50:12,000
lights in the vitor region meaning that

1436
00:50:16,790 --> 00:50:14,640
those are neutrinos and those are actual

1437
00:50:18,150 --> 00:50:16,800
astrophysical neutrino events so that

1438
00:50:19,750 --> 00:50:18,160

was the first detection by ice cube

1439
00:50:21,030 --> 00:50:19,760
astrophysical neutrinos at very high

1440
00:50:22,630 --> 00:50:21,040
energy is the ones that we're interested

1441
00:50:25,030 --> 00:50:22,640
in so that's the first ingredient to try

1442
00:50:26,470 --> 00:50:25,040
to do neutrino astronomy

1443
00:50:28,150 --> 00:50:26,480
okay so

1444
00:50:29,750 --> 00:50:28,160
ever since then in 2013 we have been

1445
00:50:32,230 --> 00:50:29,760
collecting additional evidence for

1446
00:50:33,829 --> 00:50:32,240
neutrino uh so physical neutrino

1447
00:50:35,589 --> 00:50:33,839
observations and we have a very solid

1448
00:50:37,109 --> 00:50:35,599
detection of just the neutrinos

1449
00:50:38,950 --> 00:50:37,119
themselves that's the first ingredient

1450
00:50:40,230 --> 00:50:38,960
in trying to do astronomy just figuring

1451
00:50:41,589 --> 00:50:40,240
out that there are physical neutrinos

1452
00:50:42,790 --> 00:50:41,599
out there that we can use to do

1453
00:50:44,470 --> 00:50:42,800
astronomy

1454
00:50:46,710 --> 00:50:44,480
uh and since then as i said we've been

1455
00:50:48,549 --> 00:50:46,720
building up on this uh on this uh

1456
00:50:50,069 --> 00:50:48,559
evidence for astrophysical neutrinos

1457
00:50:50,870 --> 00:50:50,079
that we have a strong detection of right

1458
00:50:52,470 --> 00:50:50,880
now

1459
00:50:54,549 --> 00:50:52,480
so where are they coming from that's the

1460
00:50:57,190 --> 00:50:54,559
next question that you may ask

1461
00:50:58,870 --> 00:50:57,200
if you plot the neutrinos not these are

1462
00:51:01,670 --> 00:50:58,880
not sources yet these are individual

1463
00:51:04,470 --> 00:51:01,680

neutrinos that you can plot in the sky

1464
00:51:06,230 --> 00:51:04,480
this what the galactic sky looks like in

1465
00:51:07,990 --> 00:51:06,240
uh in neutrinos in this kind of

1466
00:51:10,950 --> 00:51:08,000
representation the galactic plane the

1467
00:51:12,470 --> 00:51:10,960
milky way is kind of flat along this uh

1468
00:51:15,270 --> 00:51:12,480
horizontal line

1469
00:51:16,870 --> 00:51:15,280
and uh each one of these little dots is

1470
00:51:18,549 --> 00:51:16,880
not a source of neutrinos but it's a

1471
00:51:21,109 --> 00:51:18,559
single neutrino came from that that came

1472
00:51:22,790 --> 00:51:21,119
from that direction and since ice cube

1473
00:51:25,270 --> 00:51:22,800
can detect neutrinos and neutrinos can

1474
00:51:28,230 --> 00:51:25,280
go through everything you can see

1475
00:51:30,230 --> 00:51:28,240
both neutrinos coming from

1476
00:51:32,549 --> 00:51:30,240
above ice cube and also nutrients going

1477
00:51:34,549 --> 00:51:32,559
through the earth and into ice cube well

1478
00:51:36,309 --> 00:51:34,559
at some point the neutrinos are so high

1479
00:51:38,470 --> 00:51:36,319
in energy that actually some of them are

1480
00:51:41,349 --> 00:51:38,480
absorbed on the earth but you can see

1481
00:51:43,190 --> 00:51:41,359
here that we have plenty of neutrinos uh

1482
00:51:45,430 --> 00:51:43,200
across the entire sky

1483
00:51:48,870 --> 00:51:45,440
uh at the level of about as i said one

1484
00:51:51,829 --> 00:51:48,880
per month so we collect about if tens or

1485
00:51:53,750 --> 00:51:51,839
or some or so a year

1486
00:51:55,750 --> 00:51:53,760
you can see at least from just taking a

1487
00:51:57,910 --> 00:51:55,760
first look at this how these neutrino

1488
00:51:58,710 --> 00:51:57,920

events are distributed that none of them

1489
00:52:00,870 --> 00:51:58,720
or

1490
00:52:02,470 --> 00:52:00,880
there's no clear indication that most of

1491
00:52:04,470 --> 00:52:02,480
them are just distributed along the

1492
00:52:06,390 --> 00:52:04,480
galactic plane they seem to be kind of

1493
00:52:09,510 --> 00:52:06,400
distributed both above and beyond the

1494
00:52:12,950 --> 00:52:09,520
galactic plane and that tends to favor

1495
00:52:14,630 --> 00:52:12,960
that uh most of them will be coming from

1496
00:52:15,910 --> 00:52:14,640
from sources beyond our own galaxy

1497
00:52:16,870 --> 00:52:15,920
meaning that they're in exo-electric

1498
00:52:19,589 --> 00:52:16,880
space

1499
00:52:21,589 --> 00:52:19,599
so that perhaps the the contribution of

1500
00:52:24,069 --> 00:52:21,599
our own galaxy to the neutrino sky is

1501
00:52:25,910 --> 00:52:24,079
not so high compared to the nutrients

1502
00:52:26,710 --> 00:52:25,920
that we have detected so far

1503
00:52:28,470 --> 00:52:26,720
so

1504
00:52:30,150 --> 00:52:28,480
okay now we have the sample of neutrinos

1505
00:52:32,230 --> 00:52:30,160
let's look at lower energy neutrinos as

1506
00:52:34,150 --> 00:52:32,240
well to see if we see any evidence for

1507
00:52:35,829 --> 00:52:34,160
for neutrino sources right any kind of

1508
00:52:37,510 --> 00:52:35,839
particular point in the sky that's

1509
00:52:39,430 --> 00:52:37,520
emitting more neutrinos and as i said

1510
00:52:41,750 --> 00:52:39,440
before we have detected neutrinos from

1511
00:52:43,190 --> 00:52:41,760
across the sky going through the earth

1512
00:52:45,270 --> 00:52:43,200
and from above

1513
00:52:47,109 --> 00:52:45,280

and if you put them on a sky map for one

1514
00:52:49,270 --> 00:52:47,119
year of data this is what it looks like

1515
00:52:50,950 --> 00:52:49,280
and it looks pretty even right that's

1516
00:52:52,549 --> 00:52:50,960
because most of that skymap is made of

1517
00:52:54,630 --> 00:52:52,559
background events that are not really

1518
00:52:56,230 --> 00:52:54,640
astrophysical neutrinos and there's no

1519
00:52:58,630 --> 00:52:56,240
obvious indication that any of these

1520
00:53:00,230 --> 00:52:58,640
little patches of neutrinos or clusters

1521
00:53:01,349 --> 00:53:00,240
that you see are more significant than

1522
00:53:02,069 --> 00:53:01,359
others

1523
00:53:04,150 --> 00:53:02,079
so

1524
00:53:05,750 --> 00:53:04,160
in taking the first years of data we

1525
00:53:08,069 --> 00:53:05,760
didn't see any strong indications of

1526
00:53:09,510 --> 00:53:08,079
neutrino sources most of them most of

1527
00:53:11,750 --> 00:53:09,520
these neutrinos therefore most likely

1528
00:53:13,910 --> 00:53:11,760
are from background events

1529
00:53:16,150 --> 00:53:13,920
so we search for clusterings of these

1530
00:53:18,150 --> 00:53:16,160
neutrinos to look for an excess that

1531
00:53:20,069 --> 00:53:18,160
could not be produced by just random

1532
00:53:22,470 --> 00:53:20,079
alignment of background events but could

1533
00:53:24,710 --> 00:53:22,480
be a point source of neutrinos

1534
00:53:26,790 --> 00:53:24,720
and in order to find the sources we have

1535
00:53:28,630 --> 00:53:26,800
taken kind of some pointers from

1536
00:53:30,549 --> 00:53:28,640
everything else that is out there as i

1537
00:53:32,069 --> 00:53:30,559
mentioned before if we detect gamma rays

1538
00:53:33,990 --> 00:53:32,079

and neutrinos coming from a same point

1539
00:53:35,670 --> 00:53:34,000
in the sky we know that that's a good

1540
00:53:38,710 --> 00:53:35,680
indication that that could be a

1541
00:53:40,390 --> 00:53:38,720
cosmic ray source so why not use the

1542
00:53:42,390 --> 00:53:40,400
gamma rays to tell us where to look for

1543
00:53:44,549 --> 00:53:42,400
neutrino sources if you look at the

1544
00:53:46,309 --> 00:53:44,559
camera sky taking here this picture

1545
00:53:48,710 --> 00:53:46,319
across the entire sky by the feminist

1546
00:53:50,549 --> 00:53:48,720
fermi satellites that i mentioned before

1547
00:53:52,630 --> 00:53:50,559
the globe that you see here is the milky

1548
00:53:54,870 --> 00:53:52,640
way in gamma rays and each dots that you

1549
00:53:56,870 --> 00:53:54,880
see here at higher active latitudes

1550
00:53:58,870 --> 00:53:56,880
these are not stars these are super

1551
00:54:00,309 --> 00:53:58,880
massive black holes at the center of

1552
00:54:01,829 --> 00:54:00,319
these objects that we call active

1553
00:54:04,470 --> 00:54:01,839
galactic nuclei

1554
00:54:06,069 --> 00:54:04,480
okay so we can take each one of these

1555
00:54:08,309 --> 00:54:06,079
two ingredients we can take galactic

1556
00:54:09,829 --> 00:54:08,319
sources things are in our own galaxy

1557
00:54:11,829 --> 00:54:09,839
like supernova remnants ports away

1558
00:54:13,430 --> 00:54:11,839
nebulae and look for neutrinos

1559
00:54:15,109 --> 00:54:13,440
specifically in that direction so that

1560
00:54:17,270 --> 00:54:15,119
we we don't waste time just looking

1561
00:54:19,750 --> 00:54:17,280
around at the entire sky or we can also

1562
00:54:22,549 --> 00:54:19,760
look for neutrinos coming from each one

1563
00:54:24,470 --> 00:54:22,559

of these agm that we're going to

1564
00:54:25,430 --> 00:54:24,480
explore more in the in in the coming

1565
00:54:26,230 --> 00:54:25,440
slides

1566
00:54:27,589 --> 00:54:26,240
so

1567
00:54:29,589 --> 00:54:27,599
uh i will go through a bunch of

1568
00:54:31,910 --> 00:54:29,599
disappointing slides uh we have looked

1569
00:54:34,710 --> 00:54:31,920
so far at

1570
00:54:38,069 --> 00:54:34,720
nutrias from the galaxy and just based

1571
00:54:40,150 --> 00:54:38,079
on the most recent observations

1572
00:54:42,870 --> 00:54:40,160
we don't see a strong evidence for

1573
00:54:45,190 --> 00:54:42,880
emission from the galaxy itself so from

1574
00:54:47,270 --> 00:54:45,200
this kind of band of gamma ray light

1575
00:54:50,470 --> 00:54:47,280
there's no strong evidence but we're

1576
00:54:52,390 --> 00:54:50,480
fine-tuning our analysis to improve our

1577
00:54:53,910 --> 00:54:52,400
sensitivity to this neutrinos and

1578
00:54:55,589 --> 00:54:53,920
perhaps in the near future we may be

1579
00:54:57,510 --> 00:54:55,599
able to see that

1580
00:54:59,670 --> 00:54:57,520
that emission because we're getting very

1581
00:55:02,230 --> 00:54:59,680
close to what the models predict

1582
00:55:04,309 --> 00:55:02,240
should be the flux level for the

1583
00:55:05,190 --> 00:55:04,319
neutrinos coming from our own galaxy

1584
00:55:07,510 --> 00:55:05,200
okay

1585
00:55:08,950 --> 00:55:07,520
so uh so far there's no significance

1586
00:55:11,030 --> 00:55:08,960
correlations with the galactic plane but

1587
00:55:12,789 --> 00:55:11,040
as i said before our sensitivity is

1588
00:55:14,789 --> 00:55:12,799

improving as we take more data and

1589
00:55:17,270 --> 00:55:14,799
therefore at some point in some day we

1590
00:55:18,950 --> 00:55:17,280
may we may start seeing uh neutrinos

1591
00:55:20,390 --> 00:55:18,960
from our own galaxy

1592
00:55:22,549 --> 00:55:20,400
we also look in the direction of this

1593
00:55:24,710 --> 00:55:22,559
active galactic nuclei and again in that

1594
00:55:26,950 --> 00:55:24,720
case we don't see a strong evidence with

1595
00:55:28,950 --> 00:55:26,960
strong correlation between the gamma ray

1596
00:55:30,950 --> 00:55:28,960
blazars gamma-ray active galactic nuclei

1597
00:55:32,950 --> 00:55:30,960
seen by fermi and the neutrinos detected

1598
00:55:35,109 --> 00:55:32,960
by ice cube and again in that case we

1599
00:55:36,630 --> 00:55:35,119
have said okay we we don't we expected

1600
00:55:39,510 --> 00:55:36,640
perhaps some neutrinos but we haven't

1601
00:55:42,390 --> 00:55:39,520
seen any any strong evidence for that

1602
00:55:44,630 --> 00:55:42,400
yet and the other kind of very popular

1603
00:55:46,390 --> 00:55:44,640
uh source that was out there this uh

1604
00:55:48,230 --> 00:55:46,400
gamma ray burst that either produced by

1605
00:55:50,710 --> 00:55:48,240
the collapse of a massive star or the

1606
00:55:53,270 --> 00:55:50,720
compact binary merger let's say of of

1607
00:55:55,190 --> 00:55:53,280
two neutron stars they have been

1608
00:55:57,030 --> 00:55:55,200
promising neutrino sources for a long

1609
00:55:59,030 --> 00:55:57,040
time and we looked in the direction of

1610
00:56:00,950 --> 00:55:59,040
those grbs to look for neutrino emission

1611
00:56:03,990 --> 00:56:00,960
and again we haven't seen any

1612
00:56:05,510 --> 00:56:04,000
correlation okay so how do we actually

1613
00:56:06,710 --> 00:56:05,520

know that we're pointing our telescope

1614
00:56:08,230 --> 00:56:06,720
in the right direction our telescope is

1615
00:56:10,549 --> 00:56:08,240
just a block of ice that has a one key

1616
00:56:12,069 --> 00:56:10,559
number q right so how do we even can we

1617
00:56:14,150 --> 00:56:12,079
tell if we have not seen any single

1618
00:56:15,430 --> 00:56:14,160
source that our telescope is telling us

1619
00:56:17,349 --> 00:56:15,440
that neutrinos coming from the place

1620
00:56:19,589 --> 00:56:17,359
where we claim they are well it happens

1621
00:56:21,750 --> 00:56:19,599
that some of this cosmic rays beyond

1622
00:56:23,589 --> 00:56:21,760
being at best and trying we try to

1623
00:56:26,069 --> 00:56:23,599
remove them to search for neutrino

1624
00:56:28,549 --> 00:56:26,079
sources they're actually very useful

1625
00:56:30,870 --> 00:56:28,559
because cosmic rays come from

1626
00:56:33,109 --> 00:56:30,880
all around us from bombard the earth

1627
00:56:35,190 --> 00:56:33,119
from all directions but there's one

1628
00:56:37,349 --> 00:56:35,200
particular direction in which casa grays

1629
00:56:38,630 --> 00:56:37,359
tend to be coming less from i mean i

1630
00:56:40,230 --> 00:56:38,640
mean there are less consequences coming

1631
00:56:42,470 --> 00:56:40,240
from that direction and this direction

1632
00:56:43,829 --> 00:56:42,480
of the moon and the sun as you probably

1633
00:56:45,670 --> 00:56:43,839
know from solar eclipses and lunar

1634
00:56:47,589 --> 00:56:45,680
eclipses but from solar eclipses the

1635
00:56:49,829 --> 00:56:47,599
moon and the sun have the same angular

1636
00:56:50,549 --> 00:56:49,839
size in the sky half a degree

1637
00:56:52,950 --> 00:56:50,559
so

1638
00:56:56,710 --> 00:56:52,960

uh if gossip rays are coming from the

1639
00:56:58,390 --> 00:56:56,720
deep sky the space from the outer space

1640
00:57:00,069 --> 00:56:58,400
uh somewhere in the universe

1641
00:57:01,829 --> 00:57:00,079
and are getting to earth

1642
00:57:03,670 --> 00:57:01,839
uh the ones that should be coming from

1643
00:57:06,390 --> 00:57:03,680
the direction of the of the moon or the

1644
00:57:08,390 --> 00:57:06,400
sun will be actually blocked by the moon

1645
00:57:10,870 --> 00:57:08,400
and that's what we call the moon shadow

1646
00:57:12,549 --> 00:57:10,880
in cosmic rays so there should be less

1647
00:57:13,990 --> 00:57:12,559
cosmic rays hitting ice cube from the

1648
00:57:15,430 --> 00:57:14,000
direction of the moon than there would

1649
00:57:18,309 --> 00:57:15,440
be otherwise

1650
00:57:20,150 --> 00:57:18,319
so by looking at that particular shadow

1651
00:57:22,390 --> 00:57:20,160
effect we can actually

1652
00:57:24,069 --> 00:57:22,400
see the shadow i mean these are how many

1653
00:57:25,349 --> 00:57:24,079
events we see from the direction how

1654
00:57:26,950 --> 00:57:25,359
many because of grey events we see from

1655
00:57:28,950 --> 00:57:26,960
direction of the moon and you see that

1656
00:57:30,549 --> 00:57:28,960
right at the location of the moon we see

1657
00:57:32,150 --> 00:57:30,559
a strong deficit

1658
00:57:33,349 --> 00:57:32,160
that you from what you would expect

1659
00:57:36,150 --> 00:57:33,359
otherwise

1660
00:57:38,150 --> 00:57:36,160
and using that we can actually calibrate

1661
00:57:40,069 --> 00:57:38,160
our pointing because if the moon if you

1662
00:57:41,750 --> 00:57:40,079
see that shadow it means that we know

1663
00:57:42,950 --> 00:57:41,760

where these muons are pointing in the

1664
00:57:44,549 --> 00:57:42,960
sky and therefore we know where the

1665
00:57:46,150 --> 00:57:44,559
nutrients are coming from

1666
00:57:48,230 --> 00:57:46,160
and other telescopes like antares have

1667
00:57:49,510 --> 00:57:48,240
done the same thing so using the moon

1668
00:57:51,589 --> 00:57:49,520
shadow and custom grades we can actually

1669
00:57:52,870 --> 00:57:51,599
calibrate our telescopes and we know

1670
00:57:55,030 --> 00:57:52,880
that our angular resolution at the

1671
00:57:57,270 --> 00:57:55,040
moment is about 0.5 degrees improving to

1672
00:57:58,789 --> 00:57:57,280
higher energies but 0.5 degrees and in

1673
00:58:00,390 --> 00:57:58,799
terms of absolute pointing is less than

1674
00:58:03,109 --> 00:58:00,400
0.1 degrees so pretty good angular

1675
00:58:06,069 --> 00:58:03,119
pointing for neutrino telescopes

1676
00:58:08,069 --> 00:58:06,079
okay so since we started saying that

1677
00:58:09,589 --> 00:58:08,079
neutrinos have very high energies and

1678
00:58:12,630 --> 00:58:09,599
are likely astrophysical in origin now

1679
00:58:14,470 --> 00:58:12,640
we detect about once a month one a month

1680
00:58:16,150 --> 00:58:14,480
we can actually use this information

1681
00:58:19,750 --> 00:58:16,160
because if we know that there is a

1682
00:58:21,510 --> 00:58:19,760
neutrino in the sky at a particular time

1683
00:58:22,950 --> 00:58:21,520
we may not see perhaps many more

1684
00:58:24,950 --> 00:58:22,960
astrophysical neutrinos coming from that

1685
00:58:26,230 --> 00:58:24,960
same point in the sky

1686
00:58:27,510 --> 00:58:26,240
very shortly

1687
00:58:29,190 --> 00:58:27,520
but what we can do is tell the

1688
00:58:30,549 --> 00:58:29,200

astronomical community please point your

1689
00:58:31,910 --> 00:58:30,559
telescopes in that direction because

1690
00:58:33,910 --> 00:58:31,920
that means that there could be something

1691
00:58:35,510 --> 00:58:33,920
going on there at that location that is

1692
00:58:37,910 --> 00:58:35,520
emitting neutrinos and perhaps it is

1693
00:58:38,870 --> 00:58:37,920
flaring also in gamma rays in x-rays and

1694
00:58:41,270 --> 00:58:38,880
so on

1695
00:58:43,430 --> 00:58:41,280
so in ice cube we started this real time

1696
00:58:44,950 --> 00:58:43,440
on our system in 2016 you can actually

1697
00:58:46,710 --> 00:58:44,960
subscribe to it yourself and get

1698
00:58:48,549 --> 00:58:46,720
neutrino alerts every time ascii detects

1699
00:58:50,630 --> 00:58:48,559
a neutrino that is likely of a physical

1700
00:58:53,190 --> 00:58:50,640
origin and as i said before this is the

1701
00:58:55,589 --> 00:58:53,200
night this is the sky as seen from the

1702
00:58:57,190 --> 00:58:55,599
uh from the south pole the uh the

1703
00:58:58,549 --> 00:58:57,200
southern skies on the bottom the

1704
00:59:00,789 --> 00:58:58,559
northern sky that you see through the

1705
00:59:03,430 --> 00:59:00,799
earth only is on the top

1706
00:59:05,510 --> 00:59:03,440
and i'll show you a little video of the

1707
00:59:07,510 --> 00:59:05,520
start of this real-time program between

1708
00:59:10,390 --> 00:59:07,520
2016 and

1709
00:59:12,390 --> 00:59:10,400
the late part of 2017.

1710
00:59:13,750 --> 00:59:12,400
so these are the neutrinos are coming

1711
00:59:15,109 --> 00:59:13,760
and you see kind of the dates at which

1712
00:59:16,710 --> 00:59:15,119
they come and where they came from in

1713
00:59:18,230 --> 00:59:16,720

the sky and i stopped there because

1714
00:59:20,069 --> 00:59:18,240
there is one particular training event

1715
00:59:20,910 --> 00:59:20,079
that was very interesting it's called

1716
00:59:23,430 --> 00:59:20,920
this

1717
00:59:25,990 --> 00:59:23,440
i-1709-22 and that is because the date

1718
00:59:28,390 --> 00:59:26,000
that it was detected was september 17th

1719
00:59:32,230 --> 00:59:28,400
sorry september 22nd this is the typo

1720
00:59:33,670 --> 00:59:32,240
here of 2017. and this was this neutrino

1721
00:59:35,190 --> 00:59:33,680
the muon that was produced by this

1722
00:59:36,870 --> 00:59:35,200
neutrino travels through our detector

1723
00:59:39,510 --> 00:59:36,880
and it produced a pretty nice track of

1724
00:59:41,190 --> 00:59:39,520
lights and were able to reconstruct the

1725
00:59:42,069 --> 00:59:41,200
direction of that neutrino back into the

1726
00:59:44,549 --> 00:59:42,079
sky

1727
00:59:46,950 --> 00:59:44,559
and lo and behold if you look back at

1728
00:59:48,710 --> 00:59:46,960
the sky at that particular location the

1729
00:59:50,309 --> 00:59:48,720
synaptic galactic nucleus that at the

1730
00:59:52,549 --> 00:59:50,319
time of the observation of the neutrino

1731
00:59:55,430 --> 00:59:52,559
was strongly flaring in gamma rays and

1732
00:59:57,510 --> 00:59:55,440
x-rays and it was showing activity

1733
00:59:59,349 --> 00:59:57,520
throughout the electromagnetic spectrum

1734
01:00:00,870 --> 00:59:59,359
so as i said before

1735
01:00:02,230 --> 01:00:00,880
an indication that there's their gamma

1736
01:00:03,190 --> 01:00:02,240
rays at the same time as neutrino

1737
01:00:04,470 --> 01:00:03,200
emission

1738
01:00:07,349 --> 01:00:04,480

it's a good indicator that that could

1739
01:00:09,030 --> 01:00:07,359
become a cosmic ray source so this was

1740
01:00:11,430 --> 01:00:09,040
super exciting because this was the

1741
01:00:13,430 --> 01:00:11,440
first thing first time we had seen kind

1742
01:00:15,829 --> 01:00:13,440
of a coincidence between one of these

1743
01:00:17,750 --> 01:00:15,839
neutrinos we we have detected and one of

1744
01:00:19,910 --> 01:00:17,760
these uh sources and that the source at

1745
01:00:21,910 --> 01:00:19,920
the time happened to be flaring strongly

1746
01:00:24,549 --> 01:00:21,920
in gamma rays and x-rays

1747
01:00:27,589 --> 01:00:24,559
so just to mention very briefly what are

1748
01:00:30,710 --> 01:00:27,599
active galactic nuclei they're

1749
01:00:32,230 --> 01:00:30,720
the most powerful um

1750
01:00:33,910 --> 01:00:32,240
persistent sources of electromagnetic

1751
01:00:35,589 --> 01:00:33,920
radiation in the universe they're

1752
01:00:37,990 --> 01:00:35,599
powered by the supremacy black hole and

1753
01:00:39,510 --> 01:00:38,000
the matter that falls into that and many

1754
01:00:41,670 --> 01:00:39,520
of them display or at least a fraction

1755
01:00:43,349 --> 01:00:41,680
of them display these relativistic jets

1756
01:00:44,789 --> 01:00:43,359
and when these jets are pointed at us we

1757
01:00:46,789 --> 01:00:44,799
call them blazars because they're

1758
01:00:49,030 --> 01:00:46,799
shining kind of this beam of radiation

1759
01:00:50,710 --> 01:00:49,040
towards us

1760
01:00:52,309 --> 01:00:50,720
and we want to study them at the high

1761
01:00:54,309 --> 01:00:52,319
sustainable energies and of course gamma

1762
01:00:55,510 --> 01:00:54,319
rays and neutrinos are a specific way to

1763
01:00:58,069 --> 01:00:55,520

do that

1764
01:00:59,750 --> 01:00:58,079
in the detection of 17 or 9 22 this ice

1765
01:01:02,069 --> 01:00:59,760
cream nutrient event we notified as i

1766
01:01:04,150 --> 01:01:02,079
said the uh the ceramic community and

1767
01:01:05,270 --> 01:01:04,160
these were all the telescopes both on

1768
01:01:06,950 --> 01:01:05,280
the ground and in space that

1769
01:01:09,190 --> 01:01:06,960
participated in the follow-up of that

1770
01:01:11,109 --> 01:01:09,200
campaign and with the data collected

1771
01:01:13,349 --> 01:01:11,119
from those observations we were put

1772
01:01:15,670 --> 01:01:13,359
we're able to put together this picture

1773
01:01:18,309 --> 01:01:15,680
of the gamma-ray blazer

1774
01:01:20,630 --> 01:01:18,319
in this picture you see energy as if in

1775
01:01:21,990 --> 01:01:20,640
the x-axis and just the number of of

1776
01:01:24,150 --> 01:01:22,000
photons that you're seeing these are

1777
01:01:26,069 --> 01:01:24,160
just electromagnetic observations so

1778
01:01:27,670 --> 01:01:26,079
this is along the y-axis this amount of

1779
01:01:29,430 --> 01:01:27,680
energy in

1780
01:01:31,190 --> 01:01:29,440
at that particular energy range that you

1781
01:01:32,870 --> 01:01:31,200
can detect from that source

1782
01:01:35,510 --> 01:01:32,880
and um

1783
01:01:36,950 --> 01:01:35,520
here the the high energy emission is the

1784
01:01:39,030 --> 01:01:36,960
one that's most interesting because it's

1785
01:01:40,789 --> 01:01:39,040
the one that poorly is connected to

1786
01:01:43,030 --> 01:01:40,799
the neutrino emission

1787
01:01:44,470 --> 01:01:43,040
so that was the first chance correlation

1788
01:01:45,670 --> 01:01:44,480

evidence for neutrino source that we

1789
01:01:47,589 --> 01:01:45,680
have detected

1790
01:01:48,710 --> 01:01:47,599
and uh that is the evidence for the

1791
01:01:50,630 --> 01:01:48,720
connection between this particular

1792
01:01:54,309 --> 01:01:50,640
nutrient event and this blazer that we

1793
01:01:56,549 --> 01:01:54,319
detected called txs3506

1794
01:01:57,910 --> 01:01:56,559
because icecube has been operational

1795
01:01:59,829 --> 01:01:57,920
since 2010.

1796
01:02:01,510 --> 01:01:59,839
and now that we have identified a source

1797
01:02:03,430 --> 01:02:01,520
that is of particular interest we can

1798
01:02:04,549 --> 01:02:03,440
look back at the data because that scope

1799
01:02:06,549 --> 01:02:04,559
doesn't point in any particular

1800
01:02:08,950 --> 01:02:06,559
direction is always surveying the entire

1801
01:02:11,190 --> 01:02:08,960
sky so doing that

1802
01:02:13,190 --> 01:02:11,200
we actually found an excess of neutrinos

1803
01:02:16,230 --> 01:02:13,200
coming from the direction of that source

1804
01:02:18,150 --> 01:02:16,240
that dated back to 2014 and 2015. and

1805
01:02:19,750 --> 01:02:18,160
luckily no electromagnetic telescopes

1806
01:02:21,270 --> 01:02:19,760
were pointed at the source at the time

1807
01:02:24,069 --> 01:02:21,280
only wide field instruments that have

1808
01:02:25,589 --> 01:02:24,079
limited resolution and sensitivity but

1809
01:02:26,950 --> 01:02:25,599
we find additional evidence that there

1810
01:02:29,430 --> 01:02:26,960
was something going on in that part of

1811
01:02:31,270 --> 01:02:29,440
the sky so this is perhaps the first

1812
01:02:34,710 --> 01:02:31,280
evidence that we have of neutrino

1813
01:02:36,230 --> 01:02:34,720

sources appearing in the sky more recent

1814
01:02:38,150 --> 01:02:36,240
alerts i will going to show you what

1815
01:02:40,870 --> 01:02:38,160
happened after that so you can see that

1816
01:02:43,349 --> 01:02:40,880
about once a month we have a neutrino

1817
01:02:44,870 --> 01:02:43,359
alert coming from ice cube that says hey

1818
01:02:46,230 --> 01:02:44,880
look at that location in the sky because

1819
01:02:47,430 --> 01:02:46,240
there could be an astrophysical neutrino

1820
01:02:49,750 --> 01:02:47,440
coming from it

1821
01:02:53,029 --> 01:02:49,760
and this will keep going i think i made

1822
01:02:54,630 --> 01:02:53,039
this video all the way up to about 2021

1823
01:02:56,069 --> 01:02:54,640
and

1824
01:02:57,829 --> 01:02:56,079
if you want to

1825
01:02:59,910 --> 01:02:57,839
see them for with your own eyes and

1826
01:03:01,670 --> 01:02:59,920
actually get kind of a nice view of the

1827
01:03:03,109 --> 01:03:01,680
ice cube detector

1828
01:03:04,549 --> 01:03:03,119
some of our colleagues in icecube have

1829
01:03:07,029 --> 01:03:04,559
developed this

1830
01:03:09,510 --> 01:03:07,039
this app for your phone where you can

1831
01:03:10,789 --> 01:03:09,520
see a virtual reality representation of

1832
01:03:12,870 --> 01:03:10,799
icecube

1833
01:03:15,670 --> 01:03:12,880
you can get it downloaded from the play

1834
01:03:17,990 --> 01:03:15,680
store or the ice the ios app store just

1835
01:03:20,470 --> 01:03:18,000
look for ice cube ar

1836
01:03:22,230 --> 01:03:20,480
and you can actually see some of these

1837
01:03:24,069 --> 01:03:22,240
neutrino events and it will notify you

1838
01:03:26,549 --> 01:03:24,079

the alert it will notify you when you

1839
01:03:29,029 --> 01:03:26,559
have a new alert coming from icecube so

1840
01:03:30,390 --> 01:03:29,039
it takes only on average it only takes

1841
01:03:32,309 --> 01:03:30,400
30 seconds

1842
01:03:34,230 --> 01:03:32,319
for an alert for a neutrino to be

1843
01:03:35,990 --> 01:03:34,240
detected as a south pole and you getting

1844
01:03:38,150 --> 01:03:36,000
that notification so it's pretty amazing

1845
01:03:40,150 --> 01:03:38,160
what how quickly things travel from the

1846
01:03:41,829 --> 01:03:40,160
south pole all the way to your phone

1847
01:03:44,069 --> 01:03:41,839
using this technology

1848
01:03:46,069 --> 01:03:44,079
and actually we had one earlier today uh

1849
01:03:48,549 --> 01:03:46,079
today or morning i was busy sending out

1850
01:03:51,349 --> 01:03:48,559
some information about this alert this

1851
01:03:53,270 --> 01:03:51,359
is one neutrino event uh that went

1852
01:03:55,589 --> 01:03:53,280
through a detector like this

1853
01:03:57,270 --> 01:03:55,599
um and beyond the ones that we detect

1854
01:03:58,950 --> 01:03:57,280
often there have been several additional

1855
01:04:00,230 --> 01:03:58,960
claims for correlation since the

1856
01:04:02,950 --> 01:04:00,240
correlation between this particular

1857
01:04:05,589 --> 01:04:02,960
event in 2017 and this blazer called the

1858
01:04:07,190 --> 01:04:05,599
excessive ico 6. so we we may be seeing

1859
01:04:09,910 --> 01:04:07,200
kind of the tip of the iceberg in terms

1860
01:04:10,829 --> 01:04:09,920
of trying to find the sources of this uh

1861
01:04:13,190 --> 01:04:10,839
of these

1862
01:04:14,390 --> 01:04:13,200
neutrinos beyond just looking for

1863
01:04:16,470 --> 01:04:14,400

particular correlations between

1864
01:04:17,750 --> 01:04:16,480
individual neutrino events and just

1865
01:04:20,069 --> 01:04:17,760
sources that we know are out there that

1866
01:04:22,470 --> 01:04:20,079
could become resources or x-ray sources

1867
01:04:24,230 --> 01:04:22,480
we're also looking for just as i said

1868
01:04:26,710 --> 01:04:24,240
before clustering of neutrino events in

1869
01:04:28,150 --> 01:04:26,720
the sky just neutrinos if there are many

1870
01:04:30,150 --> 01:04:28,160
nutrients coming from the same point in

1871
01:04:32,789 --> 01:04:30,160
the sky that is unlikely to be produced

1872
01:04:35,349 --> 01:04:32,799
by just background by just chance it's

1873
01:04:37,750 --> 01:04:35,359
possible that that's a neutrino source

1874
01:04:40,069 --> 01:04:37,760
and in the recent analysis of 10 years

1875
01:04:42,069 --> 01:04:40,079
of ice cube data we have found an excess

1876
01:04:44,549 --> 01:04:42,079
again this is evidence for something

1877
01:04:46,390 --> 01:04:44,559
evident in the particle physics lingo

1878
01:04:47,510 --> 01:04:46,400
means that the probability that this is

1879
01:04:49,029 --> 01:04:47,520
something

1880
01:04:52,230 --> 01:04:49,039
that happened just by chance is about

1881
01:04:53,750 --> 01:04:52,240
one in 370. so it's not a very small

1882
01:04:55,190 --> 01:04:53,760
probability i mean it's not a very large

1883
01:04:56,950 --> 01:04:55,200
priority but still

1884
01:04:59,750 --> 01:04:56,960
it could be by chance that this happens

1885
01:05:01,829 --> 01:04:59,760
so we're still refining our data

1886
01:05:03,829 --> 01:05:01,839
analysis and we're looking more at this

1887
01:05:05,990 --> 01:05:03,839
data we're collecting more information

1888
01:05:07,589 --> 01:05:06,000

so perhaps if this keeps increasing we

1889
01:05:09,670 --> 01:05:07,599
will get to an actual detection of this

1890
01:05:12,150 --> 01:05:09,680
source at some point in the future we

1891
01:05:13,990 --> 01:05:12,160
don't we cannot say yet uh with the data

1892
01:05:14,950 --> 01:05:14,000
that we have in the ten years of uh so

1893
01:05:16,549 --> 01:05:14,960
far

1894
01:05:18,710 --> 01:05:16,559
okay so this particular source is very

1895
01:05:19,990 --> 01:05:18,720
interesting it's called ngc 1068 it has

1896
01:05:21,990 --> 01:05:20,000
a beautiful picture unfortunately it's

1897
01:05:23,109 --> 01:05:22,000
not taking neutrinos it's taking an

1898
01:05:24,230 --> 01:05:23,119
optical light

1899
01:05:26,069 --> 01:05:24,240
and

1900
01:05:28,950 --> 01:05:26,079
what we think is that at the center of

1901
01:05:31,670 --> 01:05:28,960
that source if that can be i mean a way

1902
01:05:34,069 --> 01:05:31,680
to explain these neutrinos uh coming

1903
01:05:36,630 --> 01:05:34,079
from that source is that

1904
01:05:39,349 --> 01:05:36,640
the the black hole at the center of that

1905
01:05:41,349 --> 01:05:39,359
galaxy has a as many of these uh black

1906
01:05:42,549 --> 01:05:41,359
holes have they have an acquisition disc

1907
01:05:43,990 --> 01:05:42,559
and they have this region called the

1908
01:05:45,910 --> 01:05:44,000
corona and that is producing many

1909
01:05:47,190 --> 01:05:45,920
photons and this acoustic grays are

1910
01:05:48,230 --> 01:05:47,200
being accelerated near the black hole

1911
01:05:49,910 --> 01:05:48,240
interact

1912
01:05:52,789 --> 01:05:49,920
with those photons and they produce

1913
01:05:55,190 --> 01:05:52,799

neutrinos and lower energy radiation

1914
01:05:57,029 --> 01:05:55,200
mostly in the x-rays so there are some

1915
01:05:59,750 --> 01:05:57,039
theories out there of how you could be

1916
01:06:01,270 --> 01:05:59,760
producing neutrinos uh to try to express

1917
01:06:04,470 --> 01:06:01,280
explain this observation this evidence

1918
01:06:06,630 --> 01:06:04,480
for neutrinos coming from my skin okay

1919
01:06:07,829 --> 01:06:06,640
so as i said the um

1920
01:06:09,430 --> 01:06:07,839
the future

1921
01:06:11,029 --> 01:06:09,440
is just to

1922
01:06:12,549 --> 01:06:11,039
get more neutrinos coming from the sky

1923
01:06:15,190 --> 01:06:12,559
as i said the ingredients do not restrow

1924
01:06:17,029 --> 01:06:15,200
me is that we want first to have the

1925
01:06:19,349 --> 01:06:17,039
cosmic flux of nutrients we have that

1926
01:06:21,349 --> 01:06:19,359
already we're improving our angle

1927
01:06:23,510 --> 01:06:21,359
resolution we're taking more data ice

1928
01:06:25,670 --> 01:06:23,520
cube is taking data 24 7. so nothing

1929
01:06:28,630 --> 01:06:25,680
stops it it looks at the dire sky at

1930
01:06:31,430 --> 01:06:28,640
once so it's no issue there

1931
01:06:33,910 --> 01:06:31,440
the thing is that ice cube

1932
01:06:34,710 --> 01:06:33,920
has a limited size so we're limited in

1933
01:06:36,789 --> 01:06:34,720
our

1934
01:06:39,349 --> 01:06:36,799
sensitivity by just the size of ice cube

1935
01:06:41,430 --> 01:06:39,359
so in the near in the next decade the

1936
01:06:43,349 --> 01:06:41,440
idea is that more

1937
01:06:44,870 --> 01:06:43,359
telescopes will be deployed and also ice

1938
01:06:46,549 --> 01:06:44,880

cube will ask you itself will be

1939
01:06:48,789 --> 01:06:46,559
expanded to look

1940
01:06:52,309 --> 01:06:48,799
more deeply into the nutrient sky

1941
01:06:56,069 --> 01:06:52,319
as i said before the um this this uh

1942
01:06:58,150 --> 01:06:56,079
effort in in russia uh to build uh this

1943
01:07:00,870 --> 01:06:58,160
to keep expanding this vital gbd

1944
01:07:03,589 --> 01:07:00,880
detector this was the status as of last

1945
01:07:04,950 --> 01:07:03,599
year right now of course things uh

1946
01:07:07,670 --> 01:07:04,960
um

1947
01:07:09,190 --> 01:07:07,680
are uncertain let's say like that uh and

1948
01:07:11,829 --> 01:07:09,200
therefore i i don't know exactly what

1949
01:07:14,150 --> 01:07:11,839
the status is of black lgbt

1950
01:07:16,150 --> 01:07:14,160
but there's also a large effort to put a

1951
01:07:18,630 --> 01:07:16,160
neutrino telescope at the bottom of the

1952
01:07:21,670 --> 01:07:18,640
mediterranean sea that's called a km3

1953
01:07:23,910 --> 01:07:21,680
nets that's mostly led by european

1954
01:07:26,309 --> 01:07:23,920
institutions and the idea is that

1955
01:07:27,510 --> 01:07:26,319
that telescope will get to

1956
01:07:29,750 --> 01:07:27,520
the volume

1957
01:07:31,349 --> 01:07:29,760
that ice cube has right now in the next

1958
01:07:33,349 --> 01:07:31,359
few years so what are the plans for ice

1959
01:07:34,710 --> 01:07:33,359
cube the idea for ice cube is that we

1960
01:07:36,710 --> 01:07:34,720
want to build the second generation of

1961
01:07:37,990 --> 01:07:36,720
ice cube guys called ice cube gen 2

1962
01:07:40,309 --> 01:07:38,000
which will be an expansion of the

1963
01:07:42,870 --> 01:07:40,319

current ice cube it can be something

1964
01:07:44,870 --> 01:07:42,880
between 6 and ten times the volume of

1965
01:07:46,150 --> 01:07:44,880
ice cubes so a much larger

1966
01:07:48,549 --> 01:07:46,160
detector that gives us better

1967
01:07:50,549 --> 01:07:48,559
sensitivity better and resolution

1968
01:07:52,069 --> 01:07:50,559
and therefore over the coming years

1969
01:07:53,510 --> 01:07:52,079
there will be

1970
01:07:55,670 --> 01:07:53,520
a lot of research and development that

1971
01:07:57,190 --> 01:07:55,680
has to go into the detector part of it

1972
01:07:59,349 --> 01:07:57,200
so there will be new strings being

1973
01:08:02,230 --> 01:07:59,359
deployed into the eyes of the softball

1974
01:08:03,910 --> 01:08:02,240
uh hopefully if the pandemic delays

1975
01:08:05,349 --> 01:08:03,920
don't keep pushing this back but the

1976
01:08:07,750 --> 01:08:05,359
idea is to push

1977
01:08:10,230 --> 01:08:07,760
kind of our sensitivity limits in terms

1978
01:08:11,430 --> 01:08:10,240
of how how sensitive we are to the

1979
01:08:12,390 --> 01:08:11,440
neutrinos that are coming from outer

1980
01:08:15,029 --> 01:08:12,400
space

1981
01:08:17,990 --> 01:08:15,039
and uh the gen 2 construction is likely

1982
01:08:20,309 --> 01:08:18,000
to continue until the 2030s early 2030s

1983
01:08:22,470 --> 01:08:20,319
but of course ice cube being modular it

1984
01:08:23,990 --> 01:08:22,480
can take data while it's being built so

1985
01:08:26,390 --> 01:08:24,000
it's not like we'll have to wait until

1986
01:08:28,789 --> 01:08:26,400
the 2030s to see something each time we

1987
01:08:30,550 --> 01:08:28,799
put a new string with light sensors into

1988
01:08:32,550 --> 01:08:30,560

the eyes we see

1989
01:08:35,110 --> 01:08:32,560
our detector improve in size and

1990
01:08:36,870 --> 01:08:35,120
therefore in sensitivity and we can get

1991
01:08:39,030 --> 01:08:36,880
a better look at the sky

1992
01:08:41,829 --> 01:08:39,040
with an ever-increasing detector

1993
01:08:43,430 --> 01:08:41,839
so in summary um i hope that even though

1994
01:08:45,030 --> 01:08:43,440
i wasn't able to show you pretty

1995
01:08:47,030 --> 01:08:45,040
pictures sticking with neutrinos other

1996
01:08:47,910 --> 01:08:47,040
than uh perhaps the sun

1997
01:08:49,590 --> 01:08:47,920
um

1998
01:08:52,070 --> 01:08:49,600
like the ones that hubble takes and the

1999
01:08:54,789 --> 01:08:52,080
ones that we're starting to get uh some

2000
01:08:56,950 --> 01:08:54,799
flavor off from jwst i think it's

2001
01:08:59,030 --> 01:08:56,960
equally as exciting that we're seeing

2002
01:09:01,110 --> 01:08:59,040
the birth of a new type of astronomy

2003
01:09:04,229 --> 01:09:01,120
that's done with neutrinos so in this

2004
01:09:07,189 --> 01:09:04,239
case we are seeing we first detected

2005
01:09:09,189 --> 01:09:07,199
this flux of astrophysical neutrinos uh

2006
01:09:10,630 --> 01:09:09,199
we may be seeing the first evidence for

2007
01:09:12,950 --> 01:09:10,640
we're seeing the first evidence for

2008
01:09:15,110 --> 01:09:12,960
sources out there and we'll keep

2009
01:09:18,709 --> 01:09:15,120
improving our data reconstruction and

2010
01:09:20,309 --> 01:09:18,719
also keep taking the data so most likely

2011
01:09:22,149 --> 01:09:20,319
we'll start to see more and more sources

2012
01:09:23,829 --> 01:09:22,159
in the coming years another thing that

2013
01:09:26,229 --> 01:09:23,839

will be important as i said before is

2014
01:09:28,149 --> 01:09:26,239
that whenever we notify the community

2015
01:09:30,149 --> 01:09:28,159
that there are telescopes out there that

2016
01:09:31,669 --> 01:09:30,159
can point back at the sky from the

2017
01:09:33,349 --> 01:09:31,679
location where these neutrinos where so

2018
01:09:35,749 --> 01:09:33,359
that we can also understand more about

2019
01:09:38,709 --> 01:09:35,759
this neutrino so we combined

2020
01:09:40,630 --> 01:09:38,719
photons with neutrinos to do this kind

2021
01:09:42,470 --> 01:09:40,640
of what we call multi-messenger approach

2022
01:09:44,950 --> 01:09:42,480
to study these sources

2023
01:09:46,630 --> 01:09:44,960
and as i said also

2024
01:09:48,630 --> 01:09:46,640
there's there are more neutrinos coming

2025
01:09:50,950 --> 01:09:48,640
online in the coming decade so please

2026
01:09:54,390 --> 01:09:50,960
stay tuned and to close i want to thank

2027
01:09:58,149 --> 01:09:54,400
again uh stsi for hosting me uh this is

2028
01:10:01,270 --> 01:09:58,159
a scam that my mother sent me from a uh

2029
01:10:04,390 --> 01:10:01,280
from kind of a book or notebook that i

2030
01:10:07,110 --> 01:10:04,400
used when i was 10 years old and as a

2031
01:10:10,310 --> 01:10:07,120
kid i was always fake excited about hst

2032
01:10:12,149 --> 01:10:10,320
about hubble and i kept notes of where

2033
01:10:14,149 --> 01:10:12,159
sdsi was in baltimore and you can see

2034
01:10:16,950 --> 01:10:14,159
kind of my drawing of what i thought

2035
01:10:18,390 --> 01:10:16,960
sdsi looked like at the time so uh i

2036
01:10:20,709 --> 01:10:18,400
mean it's a privilege for me to be part

2037
01:10:22,310 --> 01:10:20,719
of this public series because in a way

2038
01:10:24,149 --> 01:10:22,320

i'm a product of this uh the public

2039
01:10:26,390 --> 01:10:24,159
efforts of sdsi

2040
01:10:28,390 --> 01:10:26,400
uh of inspiring next generation of

2041
01:10:30,470 --> 01:10:28,400
physicists and therefore i want to thank

2042
01:10:31,510 --> 01:10:30,480
my host again for uh for having me and

2043
01:10:39,910 --> 01:10:31,520
you for

2044
01:10:43,750 --> 01:10:42,070
thank you marcos so i think

2045
01:10:45,350 --> 01:10:43,760
i'm going to have to share that picture

2046
01:10:47,669 --> 01:10:45,360
that you just shared at the end of your

2047
01:10:49,750 --> 01:10:47,679
talk of to i'm actually going to see a

2048
01:10:53,270 --> 01:10:49,760
kindergarten class tomorrow so maybe i

2049
01:10:54,630 --> 01:10:53,280
might steal that so that just great talk

2050
01:10:56,630 --> 01:10:54,640
um

2051
01:10:59,910 --> 01:10:56,640
some amazing things that i learned in

2052
01:11:02,470 --> 01:10:59,920
the talk as well and uh

2053
01:11:05,590 --> 01:11:02,480
so let me start off with some of the

2054
01:11:07,830 --> 01:11:05,600
comments that i'm looking at in the the

2055
01:11:09,910 --> 01:11:07,840
youtube chat here

2056
01:11:12,149 --> 01:11:09,920
people are very very interested in what

2057
01:11:14,310 --> 01:11:12,159
you just described in terms of neutrino

2058
01:11:15,910 --> 01:11:14,320
and particle physics here thank you for

2059
01:11:18,149 --> 01:11:15,920
the clear simplicity of your

2060
01:11:20,709 --> 01:11:18,159
explanations of this very complex field

2061
01:11:23,110 --> 01:11:20,719
it is deeply appreciated

2062
01:11:25,750 --> 01:11:23,120
absolutely incredible work so kudos to

2063
01:11:27,590 --> 01:11:25,760

you in explaining

2064
01:11:29,350 --> 01:11:27,600
how we can study the universe using

2065
01:11:31,189 --> 01:11:29,360
these particles

2066
01:11:33,270 --> 01:11:31,199
so i do have a quick question for you

2067
01:11:36,070 --> 01:11:33,280
sure have you ever been to the south

2068
01:11:38,310 --> 01:11:36,080
pole to help support ice cube not yet i

2069
01:11:40,950 --> 01:11:38,320
would love to i mean i think that

2070
01:11:42,390 --> 01:11:40,960
i had a chance in 2011 when i was a

2071
01:11:45,750 --> 01:11:42,400
grad student still

2072
01:11:48,390 --> 01:11:45,760
but i also had a baby girl on the way so

2073
01:11:49,350 --> 01:11:48,400
uh i think that was a the first priority

2074
01:11:50,550 --> 01:11:49,360
um

2075
01:11:52,630 --> 01:11:50,560
when you go to the south pole you have

2076
01:11:55,110 --> 01:11:52,640
to stay there to go

2077
01:11:58,229 --> 01:11:55,120
in and out uh for about a month

2078
01:12:00,870 --> 01:11:58,239
uh in the winter in wisconsin i mean

2079
01:12:03,590 --> 01:12:00,880
that was a pretty bad time to leave

2080
01:12:05,830 --> 01:12:03,600
my wife with a baby on the way but

2081
01:12:08,149 --> 01:12:05,840
hopefully if the pandemic uh kind of

2082
01:12:10,790 --> 01:12:08,159
restrictions are relaxed of course that

2083
01:12:12,550 --> 01:12:10,800
this is being a very remote environment

2084
01:12:14,870 --> 01:12:12,560
it's hard to intrude it's very

2085
01:12:16,149 --> 01:12:14,880
problematic to introduce a disease into

2086
01:12:19,189 --> 01:12:16,159
the the

2087
01:12:20,950 --> 01:12:19,199
south pole station so um there are many

2088
01:12:23,110 --> 01:12:20,960

precautions that are taken just to

2089
01:12:24,709 --> 01:12:23,120
prevent that and one of them is that the

2090
01:12:27,189 --> 01:12:24,719
number of people that can travel has to

2091
01:12:29,510 --> 01:12:27,199
be limited uh to the extreme

2092
01:12:31,350 --> 01:12:29,520
uh so just the kind of the the people

2093
01:12:33,189 --> 01:12:31,360
necessary to keep the station working

2094
01:12:34,790 --> 01:12:33,199
and the detectors working

2095
01:12:36,709 --> 01:12:34,800
but hopefully with the construction of

2096
01:12:38,070 --> 01:12:36,719
gen 102 there will be an uptick in the

2097
01:12:40,229 --> 01:12:38,080
number of people and hopefully i'll get

2098
01:12:42,149 --> 01:12:40,239
to join so

2099
01:12:45,110 --> 01:12:42,159
that's great yeah i think that's a

2100
01:12:46,870 --> 01:12:45,120
very unique location uh and uh only so

2101
01:12:49,189 --> 01:12:46,880
many people have been to the actual

2102
01:12:51,189 --> 01:12:49,199
south pole

2103
01:12:52,870 --> 01:12:51,199
and i can say my husband has not been to

2104
01:12:56,149 --> 01:12:52,880
the south pole but he has been in to

2105
01:12:58,709 --> 01:12:56,159
antarctica so uh um to support

2106
01:13:01,430 --> 01:12:58,719
those as long ago but that's okay um so

2107
01:13:03,270 --> 01:13:01,440
i will start off with a question

2108
01:13:05,990 --> 01:13:03,280
um here

2109
01:13:09,270 --> 01:13:06,000
that was posed in the youtube channel

2110
01:13:11,430 --> 01:13:09,280
so in the beginning of talk you showed

2111
01:13:13,110 --> 01:13:11,440
the electromagnetic spectrum from

2112
01:13:15,830 --> 01:13:13,120
microwaves all the way down to gamma

2113
01:13:18,950 --> 01:13:15,840

rays so one of the question

2114
01:13:22,070 --> 01:13:18,960
from the audience is why is the gamma

2115
01:13:24,550 --> 01:13:22,080
ray section so big on that graph and are

2116
01:13:26,790 --> 01:13:24,560
there subdivisions like uh do they have

2117
01:13:28,149 --> 01:13:26,800
names like for example i can say you

2118
01:13:30,390 --> 01:13:28,159
know infrared we talk about the near

2119
01:13:33,030 --> 01:13:30,400
infrared and the minifire infrared is

2120
01:13:34,709 --> 01:13:33,040
there something similar for gamma rays

2121
01:13:37,350 --> 01:13:34,719
that's right i can i can go back to the

2122
01:13:38,550 --> 01:13:37,360
slide if that helps

2123
01:13:40,070 --> 01:13:38,560
so

2124
01:13:41,430 --> 01:13:40,080
that will i will have to go by a little

2125
01:13:42,390 --> 01:13:41,440
bit and then

2126
01:13:45,270 --> 01:13:42,400
um

2127
01:13:47,110 --> 01:13:45,280
yes there are divisions in that very

2128
01:13:49,110 --> 01:13:47,120
wide span of uh you will think that

2129
01:13:51,510 --> 01:13:49,120
visible light when we think about

2130
01:13:54,630 --> 01:13:51,520
oh this is so different between infrared

2131
01:13:56,709 --> 01:13:54,640
and as you know i mean uh hubble and uh

2132
01:13:58,149 --> 01:13:56,719
dwst are very different telescopes

2133
01:13:59,430 --> 01:13:58,159
because they're going to be targeting

2134
01:14:02,390 --> 01:13:59,440
different parts of the electromagnetic

2135
01:14:05,669 --> 01:14:02,400
spectrum but when you look at how

2136
01:14:07,110 --> 01:14:05,679
narrow those bands are the visible uv to

2137
01:14:08,790 --> 01:14:07,120
the ir

2138
01:14:10,470 --> 01:14:08,800

and you compare that to how wide gamma

2139
01:14:12,470 --> 01:14:10,480
rays are

2140
01:14:15,669 --> 01:14:12,480
is because anything that goes above

2141
01:14:18,470 --> 01:14:15,679
let's say a few hundred thousands of the

2142
01:14:20,229 --> 01:14:18,480
times the the energy of visible light

2143
01:14:23,669 --> 01:14:20,239
that is considered gamma ray no matter

2144
01:14:25,910 --> 01:14:23,679
if your energy is 100 000 or 10 to the

2145
01:14:27,189 --> 01:14:25,920
20 electron volts so you're always a

2146
01:14:29,110 --> 01:14:27,199
gamma ray

2147
01:14:30,950 --> 01:14:29,120
the same thing applies to radio below a

2148
01:14:34,070 --> 01:14:30,960
certain energy you're always radio no

2149
01:14:36,390 --> 01:14:34,080
matter if your wavelength is a meter or

2150
01:14:38,790 --> 01:14:36,400
the the size of the universe uh you're

2151
01:14:40,790 --> 01:14:38,800
always in in radio in the radio band but

2152
01:14:42,310 --> 01:14:40,800
we have some bands we have

2153
01:14:43,669 --> 01:14:42,320
the ones that can be detected mostly

2154
01:14:46,229 --> 01:14:43,679
from outer space

2155
01:14:47,110 --> 01:14:46,239
between a few hundred of sorry a few

2156
01:14:49,750 --> 01:14:47,120
hundred

2157
01:14:52,470 --> 01:14:49,760
thousand times the the energy of visible

2158
01:14:56,149 --> 01:14:52,480
light so a few hundred kev

2159
01:14:58,070 --> 01:14:56,159
to about a few mev a few million times

2160
01:14:59,510 --> 01:14:58,080
the mass of the the energy of visible

2161
01:15:01,350 --> 01:14:59,520
light

2162
01:15:03,990 --> 01:15:01,360
that is what we call high energy gamma

2163
01:15:08,630 --> 01:15:04,000

rays up to about gv or a billion times

2164
01:15:10,229 --> 01:15:08,640
the mass of the energy and above 100 gev

2165
01:15:11,430 --> 01:15:10,239
we have very few photons coming from

2166
01:15:12,870 --> 01:15:11,440
outer space and actually that's the

2167
01:15:14,470 --> 01:15:12,880
other thing that i do that i work with

2168
01:15:15,990 --> 01:15:14,480
ice cube but also work on camera

2169
01:15:18,229 --> 01:15:16,000
instruments

2170
01:15:21,590 --> 01:15:18,239
the satellites are too small to detect

2171
01:15:22,790 --> 01:15:21,600
gamma rays above 100 gv on a steady

2172
01:15:24,870 --> 01:15:22,800
basis

2173
01:15:26,870 --> 01:15:24,880
you need something much bigger that has

2174
01:15:28,870 --> 01:15:26,880
not a size of a satellite which is a

2175
01:15:29,669 --> 01:15:28,880
couple of meters squared at most if you

2176
01:15:32,310 --> 01:15:29,679
can

2177
01:15:33,590 --> 01:15:32,320
fit it in a rocket you need hundreds of

2178
01:15:35,830 --> 01:15:33,600
thousand square meters and it's very

2179
01:15:37,270 --> 01:15:35,840
hard to launch something as big but

2180
01:15:38,390 --> 01:15:37,280
luckily we can do that from the ground

2181
01:15:40,070 --> 01:15:38,400
and actually there are there are these

2182
01:15:42,070 --> 01:15:40,080
telescopes they want to work with that's

2183
01:15:42,870 --> 01:15:42,080
that's why i include it in a very biased

2184
01:15:46,630 --> 01:15:42,880
way

2185
01:15:49,030 --> 01:15:46,640
called vedas at the long end of that um

2186
01:15:50,870 --> 01:15:49,040
of that uh electromagnetic spectrum that

2187
01:15:53,189 --> 01:15:50,880
is actually looking for gamma rays above

2188
01:15:54,709 --> 01:15:53,199

100 billion times the energy of visible

2189
01:15:57,189 --> 01:15:54,719
light from the ground actually from

2190
01:15:59,590 --> 01:15:57,199
arizona south of tucson so about 20

2191
01:16:01,590 --> 01:15:59,600
kilometers away from the mexican u.s

2192
01:16:02,870 --> 01:16:01,600
border there is vedas and there are two

2193
01:16:08,149 --> 01:16:02,880
other telescopes of this type that

2194
01:16:12,950 --> 01:16:10,709
great thank you marcus

2195
01:16:14,790 --> 01:16:12,960
i have one other question and then grant

2196
01:16:16,070 --> 01:16:14,800
i think you can join us right after that

2197
01:16:19,590 --> 01:16:16,080
question so if you go back to the

2198
01:16:23,590 --> 01:16:19,600
electromagnetic spectrum graph marcus

2199
01:16:27,990 --> 01:16:23,600
so you have that um some of the high

2200
01:16:30,950 --> 01:16:28,000
energy gamma rays are absorbed at

2201
01:16:32,709 --> 01:16:30,960
various energies to various distances

2202
01:16:35,189 --> 01:16:32,719
so in

2203
01:16:38,550 --> 01:16:35,199
specifically i'm curious to know what is

2204
01:16:40,390 --> 01:16:38,560
doing the absorbing uh towards uh close

2205
01:16:43,110 --> 01:16:40,400
by in our galactic center for some of

2206
01:16:45,910 --> 01:16:43,120
those high energy gamma rays what's the

2207
01:16:48,790 --> 01:16:45,920
absorber to make them not be

2208
01:16:50,070 --> 01:16:48,800
visible or detectable so there is a

2209
01:16:52,550 --> 01:16:50,080
remnant light

2210
01:16:53,750 --> 01:16:52,560
that permeates the entire universe

2211
01:16:55,270 --> 01:16:53,760
that goes

2212
01:16:56,709 --> 01:16:55,280
that was emitted by the first generation

2213
01:16:58,149 --> 01:16:56,719

of stars

2214
01:16:59,510 --> 01:16:58,159
that today we call the extra electric

2215
01:17:01,430 --> 01:16:59,520
background light it's very hard to

2216
01:17:02,550 --> 01:17:01,440
measure but we can actually do it with

2217
01:17:04,709 --> 01:17:02,560
gamma rays

2218
01:17:05,830 --> 01:17:04,719
and this permeates everything from i

2219
01:17:08,870 --> 01:17:05,840
mean since it's everywhere in the

2220
01:17:11,030 --> 01:17:08,880
universe it it's around us right now and

2221
01:17:12,149 --> 01:17:11,040
it's also uh far into the reaches of the

2222
01:17:13,110 --> 01:17:12,159
universe

2223
01:17:13,990 --> 01:17:13,120
um

2224
01:17:16,630 --> 01:17:14,000
so

2225
01:17:18,709 --> 01:17:16,640
this is mostly infrared light that we

2226
01:17:20,550 --> 01:17:18,719
see it today was not originally infrared

2227
01:17:22,070 --> 01:17:20,560
when it was emitted but it's mostly

2228
01:17:24,310 --> 01:17:22,080
infrared light and on top of that we

2229
01:17:28,149 --> 01:17:24,320
have the cosmic microwave background

2230
01:17:31,110 --> 01:17:28,159
so the frequencies of light that affect

2231
01:17:33,110 --> 01:17:31,120
the gamma rays um depend on the energies

2232
01:17:35,030 --> 01:17:33,120
of the cameras we're thinking about

2233
01:17:37,430 --> 01:17:35,040
most of the lower energy gamma rays at

2234
01:17:39,910 --> 01:17:37,440
the end here of the spectrum this blue

2235
01:17:41,110 --> 01:17:39,920
kind of void that you see here those are

2236
01:17:43,189 --> 01:17:41,120
affected by

2237
01:17:46,149 --> 01:17:43,199
that first generation of stars light the

2238
01:17:48,070 --> 01:17:46,159

ebl and most of the higher energy ends

2239
01:17:50,149 --> 01:17:48,080
they are coming from the causing

2240
01:17:51,430 --> 01:17:50,159
microwave background but they affect all

2241
01:17:53,189 --> 01:17:51,440
lights

2242
01:17:55,990 --> 01:17:53,199
across the entire universe

2243
01:17:57,430 --> 01:17:56,000
the thing is that um at this particular

2244
01:17:59,750 --> 01:17:57,440
energy that i'm showing here 10 to the

2245
01:18:01,430 --> 01:17:59,760
15 electron volts we cannot even see

2246
01:18:02,870 --> 01:18:01,440
into the galactic center because on top

2247
01:18:04,550 --> 01:18:02,880
of that light there is also star light

2248
01:18:06,310 --> 01:18:04,560
from the galaxy itself

2249
01:18:08,229 --> 01:18:06,320
just the the sunlight from the galaxy

2250
01:18:10,229 --> 01:18:08,239
also acts as a target

2251
01:18:12,630 --> 01:18:10,239
and this gamma rays actually interact

2252
01:18:14,550 --> 01:18:12,640
light interacts with light to produce

2253
01:18:16,070 --> 01:18:14,560
charged particles and therefore the

2254
01:18:18,550 --> 01:18:16,080
light is absorbed

2255
01:18:20,870 --> 01:18:18,560
and they never reach us so we can only

2256
01:18:22,630 --> 01:18:20,880
see for instance for that energy we only

2257
01:18:24,630 --> 01:18:22,640
see all the way up to our galaxy at

2258
01:18:26,630 --> 01:18:24,640
about 10 to the 15 volts

2259
01:18:30,390 --> 01:18:26,640
and we can see further into the universe

2260
01:18:33,990 --> 01:18:32,149
great thank you

2261
01:18:36,310 --> 01:18:34,000
so maybe um at this point we can you can

2262
01:18:37,910 --> 01:18:36,320
stop screen sharing and we'll have grant

2263
01:18:42,229 --> 01:18:37,920

come on um

2264
01:18:44,950 --> 01:18:42,239
and he will start um

2265
01:18:46,229 --> 01:18:44,960
grant if you like to start uh asking

2266
01:18:47,080 --> 01:18:46,239
some of the questions that we're seeing

2267
01:18:51,350 --> 01:18:47,090
in the chat here

2268
01:18:54,790 --> 01:18:52,630
absolutely

2269
01:18:56,870 --> 01:18:54,800
once i immute myself

2270
01:18:59,350 --> 01:18:56,880
all right so we've actually had a

2271
01:19:01,510 --> 01:18:59,360
pretty engaged audience so marcos thank

2272
01:19:03,590 --> 01:19:01,520
you there's been

2273
01:19:04,550 --> 01:19:03,600
some good discussion going on

2274
01:19:06,550 --> 01:19:04,560
um

2275
01:19:07,990 --> 01:19:06,560
all right so i'll start off with this

2276
01:19:10,709 --> 01:19:08,000
one because this one is interesting to

2277
01:19:14,709 --> 01:19:12,229
so

2278
01:19:19,189 --> 01:19:14,719
do you have any inkling as to the

2279
01:19:22,790 --> 01:19:19,199
neutrino masses like relative masses

2280
01:19:25,110 --> 01:19:22,800
ac in the comments says that different

2281
01:19:28,950 --> 01:19:25,120
masses could affect the rates of

2282
01:19:31,669 --> 01:19:28,960
oscillation then his supposition is tau

2283
01:19:33,750 --> 01:19:31,679
greater than mu

2284
01:19:35,990 --> 01:19:33,760
so that's a that's a very deep

2285
01:19:38,229 --> 01:19:36,000
particle physics question that is a big

2286
01:19:38,950 --> 01:19:38,239
problem in physics it's not just that

2287
01:19:41,030 --> 01:19:38,960
the

2288
01:19:43,189 --> 01:19:41,040

so just to rewind and put things in

2289
01:19:45,510 --> 01:19:43,199
context we know of three what we call

2290
01:19:47,430 --> 01:19:45,520
lepton particles the electron being the

2291
01:19:49,750 --> 01:19:47,440
most popular one that we know is in our

2292
01:19:51,750 --> 01:19:49,760
atoms in our body but there are also a

2293
01:19:53,350 --> 01:19:51,760
little bit more massive gases to the

2294
01:19:54,550 --> 01:19:53,360
electron that are the muon that i

2295
01:19:55,669 --> 01:19:54,560
mentioned before and also the tau

2296
01:19:57,189 --> 01:19:55,679
particle

2297
01:19:58,470 --> 01:19:57,199
and they have different

2298
01:20:01,030 --> 01:19:58,480
masses

2299
01:20:03,350 --> 01:20:01,040
the the electron has about

2300
01:20:05,750 --> 01:20:03,360
a mass of about half an mev

2301
01:20:08,790 --> 01:20:05,760
and the muon has about a mass of about

2302
01:20:11,189 --> 01:20:08,800
100 mev and then the tower is even more

2303
01:20:13,669 --> 01:20:11,199
massive what i want to say there is that

2304
01:20:15,910 --> 01:20:13,679
the flavors of these three particles

2305
01:20:19,189 --> 01:20:15,920
electron muon and tau

2306
01:20:21,350 --> 01:20:19,199
are tied to the specific masses of the

2307
01:20:23,830 --> 01:20:21,360
particles themselves

2308
01:20:25,990 --> 01:20:23,840
but neutrinos they both they also have

2309
01:20:27,590 --> 01:20:26,000
electron muon tau but the masses are

2310
01:20:29,110 --> 01:20:27,600
different and the oscillators with

2311
01:20:32,310 --> 01:20:29,120
respect to each other

2312
01:20:34,149 --> 01:20:32,320
and the question of which one comes up

2313
01:20:35,990 --> 01:20:34,159

which one is the higher mass and which

2314
01:20:37,669 --> 01:20:36,000
one is the lower mass

2315
01:20:40,470 --> 01:20:37,679
it's a very complicated one because you

2316
01:20:42,550 --> 01:20:40,480
don't have tau electron and muon you

2317
01:20:43,750 --> 01:20:42,560
have different neutrinos diff making

2318
01:20:45,510 --> 01:20:43,760
different parts of it because they

2319
01:20:47,590 --> 01:20:45,520
oscillate with each other

2320
01:20:48,950 --> 01:20:47,600
so there's a question in physics about

2321
01:20:51,669 --> 01:20:48,960
you can only measure kind of the

2322
01:20:53,910 --> 01:20:51,679
differences between the different masses

2323
01:20:55,270 --> 01:20:53,920
this is kind of going into a tangent but

2324
01:20:57,750 --> 01:20:55,280
you can only measure the difference

2325
01:21:00,470 --> 01:20:57,760
between the masses squared so you don't

2326
01:21:02,470 --> 01:21:00,480
know the sign of those differences

2327
01:21:04,629 --> 01:21:02,480
so we can have for instance the one the

2328
01:21:06,870 --> 01:21:04,639
neutrino that has the most tau

2329
01:21:08,790 --> 01:21:06,880
and then the muon and then the electron

2330
01:21:09,990 --> 01:21:08,800
order in that way like it's happening

2331
01:21:12,149 --> 01:21:10,000
with the charged versions of the

2332
01:21:14,550 --> 01:21:12,159
particles we can have what is called an

2333
01:21:16,870 --> 01:21:14,560
inverted hierarchy where we have one of

2334
01:21:18,149 --> 01:21:16,880
them being much heavier and the other

2335
01:21:20,070 --> 01:21:18,159
ones at the bottom

2336
01:21:22,870 --> 01:21:20,080
so actually i don't have that many i

2337
01:21:25,590 --> 01:21:22,880
don't have a good intuition for that uh

2338
01:21:27,270 --> 01:21:25,600

if i had to bet i mean unfortunately

2339
01:21:28,950 --> 01:21:27,280
there is one solution that will be very

2340
01:21:30,709 --> 01:21:28,960
easy to measure if it's

2341
01:21:31,750 --> 01:21:30,719
normal hierarchy or invert

2342
01:21:33,430 --> 01:21:31,760
inverted

2343
01:21:34,950 --> 01:21:33,440
uh and the other one it will take a long

2344
01:21:37,110 --> 01:21:34,960
time to measure

2345
01:21:39,030 --> 01:21:37,120
but i don't have a horse on that on the

2346
01:21:42,790 --> 01:21:39,040
race unfortunately i know that a lot of

2347
01:21:44,310 --> 01:21:42,800
my neutrino colleagues do

2348
01:21:45,669 --> 01:21:44,320
it's a lot more information than i

2349
01:21:47,669 --> 01:21:45,679
started with so

2350
01:21:49,990 --> 01:21:47,679
i appreciate it i like to ask those

2351
01:21:51,750 --> 01:21:50,000
because i come in as a non-astronomer as

2352
01:21:54,629 --> 01:21:51,760
well so i try to pick out the stuff that

2353
01:21:59,110 --> 01:21:54,639
i have no idea

2354
01:22:02,390 --> 01:22:00,870
oh uh there were quite a few questions

2355
01:22:03,270 --> 01:22:02,400
about ice cube

2356
01:22:05,510 --> 01:22:03,280
um

2357
01:22:07,990 --> 01:22:05,520
one of them being do you have any idea

2358
01:22:11,270 --> 01:22:08,000
as to the time frame

2359
01:22:14,390 --> 01:22:11,280
as to when ice cube will become

2360
01:22:16,870 --> 01:22:14,400
available and start doing more science

2361
01:22:19,110 --> 01:22:16,880
as you were talking about earlier

2362
01:22:20,629 --> 01:22:19,120
so you if this is about i mean ice cube

2363
01:22:22,709 --> 01:22:20,639

is operating right now

2364
01:22:25,189 --> 01:22:22,719
and in terms of making that data

2365
01:22:25,990 --> 01:22:25,199
available to the public for instance or

2366
01:22:29,030 --> 01:22:26,000
the

2367
01:22:31,189 --> 01:22:29,040
community

2368
01:22:32,229 --> 01:22:31,199
we have data releases uh that we send

2369
01:22:34,709 --> 01:22:32,239
out

2370
01:22:36,870 --> 01:22:34,719
very recently we released 10 years of

2371
01:22:38,629 --> 01:22:36,880
data this essentially the entire data

2372
01:22:41,110 --> 01:22:38,639
set of ice cube it's out there for you

2373
01:22:43,510 --> 01:22:41,120
to download if you go to icecube.edu you

2374
01:22:45,110 --> 01:22:43,520
can download 10 years worth of neutrino

2375
01:22:46,470 --> 01:22:45,120
observations and try to see if you can

2376
01:22:47,910 --> 01:22:46,480
find the source

2377
01:22:49,430 --> 01:22:47,920
we have been looking through with this

2378
01:22:51,430 --> 01:22:49,440
data but there could be out there people

2379
01:22:53,270 --> 01:22:51,440
that think that perhaps it's not agn for

2380
01:22:55,030 --> 01:22:53,280
instance there could be some other weird

2381
01:22:57,110 --> 01:22:55,040
type of source and therefore if you look

2382
01:22:58,629 --> 01:22:57,120
at those specific points in the sky

2383
01:22:59,830 --> 01:22:58,639
if if they're coming if there are more

2384
01:23:02,470 --> 01:22:59,840
neutrinos coming from that direction

2385
01:23:04,470 --> 01:23:02,480
that you would expect from just chance

2386
01:23:07,590 --> 01:23:04,480
then you have a solid detection

2387
01:23:10,149 --> 01:23:07,600
of a neutrino source uh so that that is

2388
01:23:12,790 --> 01:23:10,159

is there for available and in terms of

2389
01:23:14,550 --> 01:23:12,800
just the continuation of icecube we keep

2390
01:23:17,350 --> 01:23:14,560
taking data all the time as i mentioned

2391
01:23:19,830 --> 01:23:17,360
we just saw an alert this morning

2392
01:23:22,070 --> 01:23:19,840
um luckily i'm still very jet lagged

2393
01:23:23,590 --> 01:23:22,080
from the trip to paris so i i was still

2394
01:23:25,110 --> 01:23:23,600
awake when it happened so i could

2395
01:23:26,550 --> 01:23:25,120
respond quickly

2396
01:23:27,430 --> 01:23:26,560
but beyond that

2397
01:23:29,430 --> 01:23:27,440
we

2398
01:23:31,350 --> 01:23:29,440
will keep taking data until the

2399
01:23:33,110 --> 01:23:31,360
construction of gen 2 and ice cube

2400
01:23:35,830 --> 01:23:33,120
itself let's say the current generation

2401
01:23:37,669 --> 01:23:35,840
ice cube will become a part of gen 2

2402
01:23:39,910 --> 01:23:37,679
because it will be just a larger volume

2403
01:23:42,070 --> 01:23:39,920
surrounding the existing ice cube so as

2404
01:23:43,910 --> 01:23:42,080
the the detector expands we won't stop

2405
01:23:47,350 --> 01:23:43,920
taking data we'll just keep going and

2406
01:23:48,790 --> 01:23:47,360
improve the sensitivity of the telescope

2407
01:23:52,149 --> 01:23:48,800
i think that's more what they were

2408
01:23:54,950 --> 01:23:52,159
asking yeah thank you

2409
01:23:58,470 --> 01:23:54,960
um okay so

2410
01:24:01,189 --> 01:23:58,480
moving forward as well um again ice cube

2411
01:24:02,870 --> 01:24:01,199
how long do you expect the sensors

2412
01:24:05,110 --> 01:24:02,880
to last

2413
01:24:08,390 --> 01:24:05,120

they're super stable i mean likely for

2414
01:24:09,910 --> 01:24:08,400
us they're uh i mean is not i mean i

2415
01:24:11,910 --> 01:24:09,920
want i don't want to compare it to

2416
01:24:13,430 --> 01:24:11,920
launching a space telescope because i

2417
01:24:15,430 --> 01:24:13,440
know that i'm the wrong place to be

2418
01:24:17,030 --> 01:24:15,440
bragging about something like that but

2419
01:24:19,110 --> 01:24:17,040
it feels a lot like that because you

2420
01:24:20,550 --> 01:24:19,120
drill into the eyes and you put them

2421
01:24:22,709 --> 01:24:20,560
there and there's no easy way to take

2422
01:24:26,149 --> 01:24:22,719
them out so there's no repair for the

2423
01:24:28,950 --> 01:24:26,159
sensors that you deploy and this i mean

2424
01:24:32,070 --> 01:24:28,960
assuming that uh will keep the ice the

2425
01:24:33,270 --> 01:24:32,080
ice the softball frozen for a long time

2426
01:24:35,110 --> 01:24:33,280
um

2427
01:24:36,950 --> 01:24:35,120
those should be there for tens of

2428
01:24:37,750 --> 01:24:36,960
thousands of years perhaps that's the

2429
01:24:40,629 --> 01:24:37,760
the

2430
01:24:42,629 --> 01:24:40,639
pole

2431
01:24:44,390 --> 01:24:42,639
so the only thing that actually kills

2432
01:24:46,390 --> 01:24:44,400
the sensors is actually power cycling

2433
01:24:48,149 --> 01:24:46,400
them because sometimes there are some

2434
01:24:51,350 --> 01:24:48,159
sensors there they have small computers

2435
01:24:54,070 --> 01:24:51,360
in them and like with any computer uh if

2436
01:24:55,590 --> 01:24:54,080
you power cycle things enough you have a

2437
01:24:57,189 --> 01:24:55,600
probability that one of those power

2438
01:24:58,629 --> 01:24:57,199

cycles the computer will not come back

2439
01:25:01,189 --> 01:24:58,639
and there's nobody to press a reset

2440
01:25:03,189 --> 01:25:01,199
button to go down there so

2441
01:25:04,470 --> 01:25:03,199
that's how we've we've lost some sensors

2442
01:25:06,390 --> 01:25:04,480
but out of the

2443
01:25:08,470 --> 01:25:06,400
uh more than 5000 we have deployed we

2444
01:25:09,510 --> 01:25:08,480
have lost a tiny fraction

2445
01:25:15,030 --> 01:25:09,520
in uh

2446
01:25:16,870 --> 01:25:15,040
well now 12 years of operation so

2447
01:25:19,270 --> 01:25:16,880
things are looking great and uh

2448
01:25:21,510 --> 01:25:19,280
it's a slightly i mean the health of the

2449
01:25:23,510 --> 01:25:21,520
instrument is not an issue unfortunately

2450
01:25:25,110 --> 01:25:23,520
uh fortunately for us

2451
01:25:27,110 --> 01:25:25,120
and i would imagine that and this is

2452
01:25:29,910 --> 01:25:27,120
piggybacking on another question here i

2453
01:25:31,350 --> 01:25:29,920
would imagine that drilling as far down

2454
01:25:32,550 --> 01:25:31,360
and setting them up in the way that you

2455
01:25:35,510 --> 01:25:32,560
do

2456
01:25:37,189 --> 01:25:35,520
climate change slash like ice melting

2457
01:25:38,870 --> 01:25:37,199
that sort of stuff is not an issue

2458
01:25:41,189 --> 01:25:38,880
because of how far down you're going

2459
01:25:43,910 --> 01:25:41,199
exactly yeah if there's any issue is

2460
01:25:46,709 --> 01:25:43,920
that the glacier itself is uh is sliding

2461
01:25:48,790 --> 01:25:46,719
i mean at the south pole uh you're still

2462
01:25:50,310 --> 01:25:48,800
on top of a glacier and that glacier is

2463
01:25:51,510 --> 01:25:50,320

moving with a speed of about 10 meters

2464
01:25:53,830 --> 01:25:51,520
per year

2465
01:25:55,750 --> 01:25:53,840
so the whole thing is sliding

2466
01:25:57,750 --> 01:25:55,760
sideways and the south pole station as

2467
01:25:59,350 --> 01:25:57,760
well on top of it

2468
01:26:01,590 --> 01:25:59,360
but the thing is that if there happens

2469
01:26:02,950 --> 01:26:01,600
to be sheer between different layers of

2470
01:26:04,149 --> 01:26:02,960
the eyes for instance the eyes remember

2471
01:26:05,590 --> 01:26:04,159
that the detector itself is one

2472
01:26:07,750 --> 01:26:05,600
kilometer tall

2473
01:26:10,149 --> 01:26:07,760
so if this will slightly

2474
01:26:12,070 --> 01:26:10,159
different base of let's say motion

2475
01:26:13,910 --> 01:26:12,080
between the bottom and the top

2476
01:26:15,750 --> 01:26:13,920
that could lead to the cable snapping at

2477
01:26:16,629 --> 01:26:15,760
some point so i think that that's the

2478
01:26:17,510 --> 01:26:16,639
only

2479
01:26:19,590 --> 01:26:17,520
risk

2480
01:26:21,030 --> 01:26:19,600
but i don't think we are anywhere close

2481
01:26:22,390 --> 01:26:21,040
to that being an issue because most of

2482
01:26:23,830 --> 01:26:22,400
that ice moves

2483
01:26:25,430 --> 01:26:23,840
as a solid block as most of these

2484
01:26:27,990 --> 01:26:25,440
glaciers do

2485
01:26:29,990 --> 01:26:28,000
so in doing so it wouldn't affect the

2486
01:26:31,750 --> 01:26:30,000
majority of your

2487
01:26:33,350 --> 01:26:31,760
uh your science or your instrument

2488
01:26:34,550 --> 01:26:33,360

that's right because it just moves a

2489
01:26:37,189 --> 01:26:34,560
little bit to the

2490
01:26:39,270 --> 01:26:37,199
side and then we we keep anyway we keep

2491
01:26:41,510 --> 01:26:39,280
track of the geometry of the detector we

2492
01:26:44,070 --> 01:26:41,520
have light sensors where each one of

2493
01:26:46,870 --> 01:26:44,080
this uh um this light sensor is also

2494
01:26:49,030 --> 01:26:46,880
kind of its own disco ball it has leds

2495
01:26:50,950 --> 01:26:49,040
on it and then we make them flash and

2496
01:26:52,950 --> 01:26:50,960
when we make them flash we record the

2497
01:26:55,350 --> 01:26:52,960
light that is seen by the others by the

2498
01:26:57,669 --> 01:26:55,360
other sensors and since we know the

2499
01:26:59,189 --> 01:26:57,679
speed of light you can know

2500
01:27:00,390 --> 01:26:59,199
i mean if you know when you emitted the

2501
01:27:02,310 --> 01:27:00,400
pulse of light

2502
01:27:04,310 --> 01:27:02,320
and you know how how long it took the

2503
01:27:07,110 --> 01:27:04,320
other one to record it you can know the

2504
01:27:08,550 --> 01:27:07,120
distance right between any two sensors

2505
01:27:10,470 --> 01:27:08,560
and if you have this three-dimensional

2506
01:27:12,229 --> 01:27:10,480
object you can do a lot of math to

2507
01:27:13,910 --> 01:27:12,239
figure out how far is each one with

2508
01:27:15,430 --> 01:27:13,920
respect to the other and figure out the

2509
01:27:17,030 --> 01:27:15,440
geometry of the of the telescope and

2510
01:27:18,709 --> 01:27:17,040
that's actually one of one of my

2511
01:27:20,310 --> 01:27:18,719
colleagues at the university of alabama

2512
01:27:21,910 --> 01:27:20,320
which is the calibration of the of the

2513
01:27:24,550 --> 01:27:21,920

geometry and we have a good track of we

2514
01:27:27,110 --> 01:27:24,560
keep good track of that too

2515
01:27:28,550 --> 01:27:27,120
you just answered the question um i was

2516
01:27:30,470 --> 01:27:28,560
about to ask and

2517
01:27:31,830 --> 01:27:30,480
i could see it all i was like i'm

2518
01:27:33,430 --> 01:27:31,840
thinking about you know with with

2519
01:27:36,229 --> 01:27:33,440
electromagnetic

2520
01:27:38,790 --> 01:27:36,239
doing flux calibrations and flat fields

2521
01:27:39,990 --> 01:27:38,800
and knowing all the details about your

2522
01:27:41,430 --> 01:27:40,000
instrument

2523
01:27:43,030 --> 01:27:41,440
it's just a different way of doing it

2524
01:27:46,790 --> 01:27:43,040
yeah i think yeah

2525
01:27:50,950 --> 01:27:46,800
um ice cube is such a it's such a

2526
01:27:53,750 --> 01:27:50,960
creative experiment to to be able to

2527
01:27:56,790 --> 01:27:53,760
do what we need to do to get the very

2528
01:27:59,430 --> 01:27:56,800
um small number of detections that are

2529
01:28:01,189 --> 01:27:59,440
that are better that we're finding

2530
01:28:03,110 --> 01:28:01,199
and one of the things in the beginning i

2531
01:28:05,030 --> 01:28:03,120
think you said um

2532
01:28:07,830 --> 01:28:05,040
there's you know through your lifetime i

2533
01:28:09,669 --> 01:28:07,840
believe was the the um the statistic

2534
01:28:11,830 --> 01:28:09,679
that you have a 50 50 chance of one

2535
01:28:13,669 --> 01:28:11,840
neutrino potentially interacting with

2536
01:28:15,830 --> 01:28:13,679
your body is that correct okay yes so

2537
01:28:17,750 --> 01:28:15,840
what would happen if a neutrino did

2538
01:28:19,669 --> 01:28:17,760

interact with your body that's a good

2539
01:28:22,070 --> 01:28:19,679
question so luckily the neutrinos that

2540
01:28:23,750 --> 01:28:22,080
go through us have low energies in terms

2541
01:28:25,350 --> 01:28:23,760
of this like a million times the the

2542
01:28:27,510 --> 01:28:25,360
energy of visible light

2543
01:28:28,390 --> 01:28:27,520
but still that amount of energy is very

2544
01:28:30,149 --> 01:28:28,400
very small

2545
01:28:32,149 --> 01:28:30,159
on top of that it's not that the entire

2546
01:28:34,390 --> 01:28:32,159
neutrino energy is dumped into the body

2547
01:28:37,510 --> 01:28:34,400
it's just a tiny fraction perhaps one k

2548
01:28:39,430 --> 01:28:37,520
a few kv a few kilo electron volts so at

2549
01:28:41,110 --> 01:28:39,440
most there will be like just one single

2550
01:28:44,870 --> 01:28:41,120
x-ray

2551
01:28:47,350 --> 01:28:44,880
do to like uh

2552
01:28:49,430 --> 01:28:47,360
uh to look at our bones but a single

2553
01:28:51,430 --> 01:28:49,440
photon an x-ray photon going through our

2554
01:28:53,110 --> 01:28:51,440
body once in a lifetime

2555
01:28:56,390 --> 01:28:53,120
uh there are many more x-rays that we

2556
01:28:58,229 --> 01:28:56,400
are exposed to uh from from things

2557
01:29:00,950 --> 01:28:58,239
around us and also going to the doctor

2558
01:29:02,629 --> 01:29:00,960
so that's not that's not an issue yeah i

2559
01:29:04,470 --> 01:29:02,639
know the general public always wants to

2560
01:29:05,669 --> 01:29:04,480
know should i be worried so now i can

2561
01:29:07,510 --> 01:29:05,679
tell them no you don't have to be

2562
01:29:08,629 --> 01:29:07,520
worried

2563
01:29:10,070 --> 01:29:08,639

yeah it would be great if we could

2564
01:29:11,910 --> 01:29:10,080
detect neutrinos more easily and they

2565
01:29:14,310 --> 01:29:11,920
were it was a problem but uh yeah they

2566
01:29:17,350 --> 01:29:14,320
go through us so it's hard that is

2567
01:29:20,870 --> 01:29:19,750
all right well um i've got two more and

2568
01:29:25,270 --> 01:29:20,880
i think we'll

2569
01:29:28,790 --> 01:29:25,280
two final questions sounds good grant

2570
01:29:32,629 --> 01:29:28,800
one follow-up and one one new one um

2571
01:29:34,390 --> 01:29:32,639
so will there be an ice cube phase three

2572
01:29:37,830 --> 01:29:34,400
oh i would love that though if they

2573
01:29:41,669 --> 01:29:37,840
could ask you phase three um when ice

2574
01:29:43,510 --> 01:29:41,679
cube was built its predecessor amanda

2575
01:29:45,750 --> 01:29:43,520
was also there at south pole as a much

2576
01:29:47,270 --> 01:29:45,760
smaller version of ice cube

2577
01:29:49,350 --> 01:29:47,280
um and it was

2578
01:29:51,030 --> 01:29:49,360
i mean it was ice cube was predicated on

2579
01:29:52,550 --> 01:29:51,040
the fact that

2580
01:29:54,070 --> 01:29:52,560
amanda was not big enough to see

2581
01:29:55,750 --> 01:29:54,080
astrophysical neutrinos and he never saw

2582
01:29:58,149 --> 01:29:55,760
us for physical neutrinos and there was

2583
01:29:59,910 --> 01:29:58,159
a good reason for that so icy was built

2584
01:30:02,790 --> 01:29:59,920
saying this is the one that would

2585
01:30:04,149 --> 01:30:02,800
actually see the physical neutrinos

2586
01:30:05,830 --> 01:30:04,159
and we got that

2587
01:30:07,350 --> 01:30:05,840
now the next thing is okay now we have

2588
01:30:09,510 --> 01:30:07,360

the astrophysical neutrinos we need more

2589
01:30:11,350 --> 01:30:09,520
neutrinos to see sources and do

2590
01:30:12,629 --> 01:30:11,360
reasoning with them like

2591
01:30:13,830 --> 01:30:12,639
measuring fluxes like you're doing

2592
01:30:15,669 --> 01:30:13,840
astronomy

2593
01:30:17,350 --> 01:30:15,679
getting spectra for sources getting

2594
01:30:18,390 --> 01:30:17,360
things like this in neutrinos not in

2595
01:30:19,590 --> 01:30:18,400
light

2596
01:30:22,149 --> 01:30:19,600
um

2597
01:30:24,310 --> 01:30:22,159
the more you found the more you needed

2598
01:30:26,629 --> 01:30:24,320
science that's uh we're greedy we're

2599
01:30:28,790 --> 01:30:26,639
greedy so um

2600
01:30:31,270 --> 01:30:28,800
once ice cube gen 2 is operational

2601
01:30:33,110 --> 01:30:31,280
hopefully sees plenty of sources

2602
01:30:34,950 --> 01:30:33,120
i think it will determine also what the

2603
01:30:36,390 --> 01:30:34,960
next generation telescope will look like

2604
01:30:39,350 --> 01:30:36,400
in terms of what we can see and what we

2605
01:30:41,189 --> 01:30:39,360
can learn from these observations

2606
01:30:42,790 --> 01:30:41,199
all right and um i'm going to finish

2607
01:30:44,950 --> 01:30:42,800
this off with a follow-up from the

2608
01:30:48,229 --> 01:30:44,960
gentleman from earlier um are the

2609
01:30:51,669 --> 01:30:48,239
detectors basically photo multiplier

2610
01:30:53,110 --> 01:30:51,679
tubes and could light avalanche diodes

2611
01:30:55,510 --> 01:30:53,120
be more efficient

2612
01:30:58,390 --> 01:30:55,520
in capturing very good questions very

2613
01:31:00,390 --> 01:30:58,400

technical yes pmt's photo multiplier

2614
01:31:02,149 --> 01:31:00,400
tubes are the ones that we use

2615
01:31:04,629 --> 01:31:02,159
and the photomultiplier tubes are good

2616
01:31:06,310 --> 01:31:04,639
because they um so for

2617
01:31:08,470 --> 01:31:06,320
think about it in terms of an inverted

2618
01:31:10,870 --> 01:31:08,480
light light bulb in lightbulb you run

2619
01:31:12,629 --> 01:31:10,880
current through it and you emit slides

2620
01:31:15,110 --> 01:31:12,639
in this case you have a photocathode

2621
01:31:17,110 --> 01:31:15,120
that is a photoelectric

2622
01:31:19,110 --> 01:31:17,120
material that whenever you have a photon

2623
01:31:21,110 --> 01:31:19,120
hitting it you produce an electron so it

2624
01:31:22,950 --> 01:31:21,120
produces a little bit of electricity and

2625
01:31:25,830 --> 01:31:22,960
we have a way of multiplying that

2626
01:31:29,030 --> 01:31:25,840
electricity that electron into a signal

2627
01:31:30,950 --> 01:31:29,040
that we can measure okay so the photo

2628
01:31:32,390 --> 01:31:30,960
this photo multiplier too these pmts are

2629
01:31:33,990 --> 01:31:32,400
very good because we can build them

2630
01:31:35,750 --> 01:31:34,000
pretty big

2631
01:31:37,750 --> 01:31:35,760
and therefore any photon that hits the

2632
01:31:40,790 --> 01:31:37,760
pmt across the entire surface of the

2633
01:31:42,070 --> 01:31:40,800
photocathode will result in a signal

2634
01:31:42,870 --> 01:31:42,080
and since

2635
01:31:45,669 --> 01:31:42,880
this

2636
01:31:48,229 --> 01:31:45,679
sensors are separated by tens of meters

2637
01:31:50,149 --> 01:31:48,239
with respect to the next one and 125

2638
01:31:52,149 --> 01:31:50,159

meters horizontally from the other one

2639
01:31:55,030 --> 01:31:52,159
you want a big area for your photo

2640
01:31:57,270 --> 01:31:55,040
sensors so that uh any photon that is

2641
01:31:58,470 --> 01:31:57,280
produced by this muons actually creates

2642
01:32:00,470 --> 01:31:58,480
a signal

2643
01:32:03,030 --> 01:32:00,480
um so that will be much more difficult

2644
01:32:04,950 --> 01:32:03,040
to do with any kind of silicon based uh

2645
01:32:07,669 --> 01:32:04,960
detector because silicon based you can

2646
01:32:09,830 --> 01:32:07,679
only bit big i mean build them so big

2647
01:32:11,430 --> 01:32:09,840
and if you want to build a gigantic

2648
01:32:12,950 --> 01:32:11,440
surface you'll have to it will be

2649
01:32:14,790 --> 01:32:12,960
extremely expensive

2650
01:32:17,110 --> 01:32:14,800
each one of these photos photo

2651
01:32:19,110 --> 01:32:17,120
multiplier tubes that we have the sensor

2652
01:32:20,950 --> 01:32:19,120
itself costs about between a thousand

2653
01:32:23,750 --> 01:32:20,960
and two thousand dollars but if you have

2654
01:32:26,550 --> 01:32:23,760
to deploy five thousand of them

2655
01:32:28,550 --> 01:32:26,560
that's a lot of money perhaps not jwst

2656
01:32:31,750 --> 01:32:28,560
money but still

2657
01:32:34,229 --> 01:32:31,760
a lot of money so um we could but it's

2658
01:32:36,470 --> 01:32:34,239
just not economical um

2659
01:32:39,270 --> 01:32:36,480
to do so but we're still looking at

2660
01:32:42,070 --> 01:32:39,280
different technologies for gen 2 perhaps

2661
01:32:43,990 --> 01:32:42,080
have a segmented pmt

2662
01:32:45,669 --> 01:32:44,000
uh that can reconstruct also where the

2663
01:32:48,390 --> 01:32:45,679

light was coming from and just not tell

2664
01:32:51,030 --> 01:32:48,400
you yeah i saw light that's it but also

2665
01:32:52,990 --> 01:32:51,040
where the light was coming from

2666
01:32:55,189 --> 01:32:53,000
one day great

2667
01:32:57,830 --> 01:32:55,199
[Music]

2668
01:32:58,470 --> 01:32:57,840
well thank you so much marcus for thank

2669
01:33:01,110 --> 01:32:58,480
you

2670
01:33:03,030 --> 01:33:01,120
joining us for this public lecture

2671
01:33:05,510 --> 01:33:03,040
series um

2672
01:33:07,830 --> 01:33:05,520
we learned a lot about neutrino physics

2673
01:33:11,030 --> 01:33:07,840
and understanding how we can uncover

2674
01:33:13,750 --> 01:33:11,040
more details about astrophysical sources

2675
01:33:15,030 --> 01:33:13,760
i encourage everybody to go out and

2676
01:33:19,350 --> 01:33:15,040
follow

2677
01:33:20,870 --> 01:33:19,360
cube neutrino observatory so i can hear

2678
01:33:22,709 --> 01:33:20,880
what's going on

2679
01:33:24,870 --> 01:33:22,719
down in the south pole

2680
01:33:26,629 --> 01:33:24,880
and uh looking forward to sharing and

2681
01:33:28,550 --> 01:33:26,639
looking at that app as well because

2682
01:33:30,070 --> 01:33:28,560
since there's so few knowing which ones

2683
01:33:31,350 --> 01:33:30,080
are coming through is it's important to

2684
01:33:33,669 --> 01:33:31,360
us that's right

2685
01:33:35,350 --> 01:33:33,679
we can give them all all names right

2686
01:33:37,350 --> 01:33:35,360
well thank you again

2687
01:33:40,070 --> 01:33:37,360
thank you to those of you who are

2688
01:33:42,950 --> 01:33:40,080

listening in real time uh keep an eye

2689
01:33:45,510 --> 01:33:42,960
out for next month's uh public lecture

2690
01:33:48,709 --> 01:33:45,520
series with dr frank summers talking

2691
01:33:50,709 --> 01:33:48,719
about ada uh karina and some great

2692
01:33:53,430 --> 01:33:50,719
visualizations i'm sure

2693
01:33:55,110 --> 01:33:53,440
that he will be sharing and uh sign up

2694
01:33:58,310 --> 01:33:55,120
and get announcements for our future

2695
01:34:00,390 --> 01:33:58,320
talks so thank you and good night to you

2696
01:34:01,270 --> 01:34:00,400
all out there