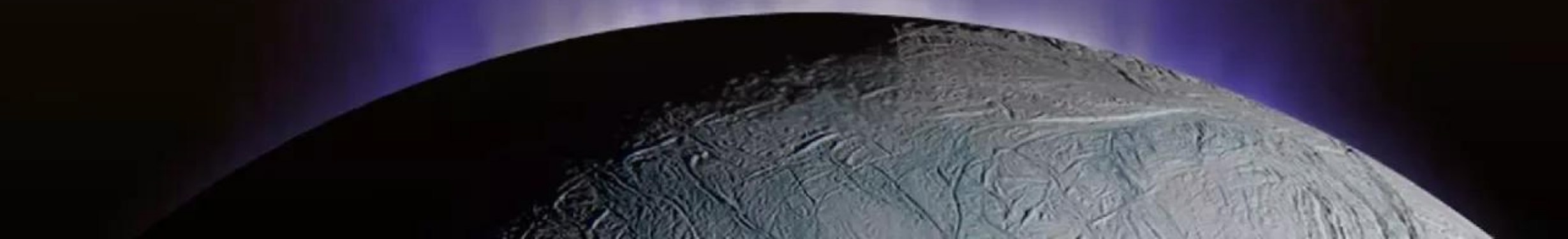


PUBLIC LECTURE SERIES

**The Plumes of Europa:
Ice, Water, Life?**

Featuring Guest Speaker:
Susana Deustua



1
00:00:04,430 --> 00:00:02,330
I'll scope public lecture series it is

2
00:00:06,769 --> 00:00:04,440
my pleasure to be your host I'm dr.

3
00:00:08,839 --> 00:00:06,779
Frank summers of the office of public

4
00:00:12,259 --> 00:00:08,849
outreach here at the Space Telescope

5
00:00:14,839 --> 00:00:12,269
Science Institute and when you came in

6
00:00:18,200 --> 00:00:14,849
if you notice them we have pictures

7
00:00:20,359 --> 00:00:18,210
we call these lithographs this one is of

8
00:00:23,179 --> 00:00:20,369
a brand-new one Nevernever everything

9
00:00:25,790 --> 00:00:23,189
this is the multi-wavelength Crab Nebula

10
00:00:27,609 --> 00:00:25,800
what do we mean by multi-wavelength well

11
00:00:29,810 --> 00:00:27,619
if you turn over you can see that this

12
00:00:33,470 --> 00:00:29,820
individual image the different colors

13
00:00:36,080 --> 00:00:33,480

are composed of light from six different

14

00:00:39,260 --> 00:00:36,090

five different wavelengths okay from

15

00:00:41,299 --> 00:00:39,270

x-ray all the way to radio and we have

16

00:00:43,850 --> 00:00:41,309

some explanatory text you didn't grab

17

00:00:47,690 --> 00:00:43,860

one on the way in for have one now or on

18

00:00:55,160 --> 00:00:47,700

your way out our talk tonight is the

19

00:00:56,779 --> 00:00:55,170

plumes of Europa ice water life which

20

00:00:58,939 --> 00:00:56,789

Susannah thought would be a cool title

21

00:01:02,200 --> 00:00:58,949

to bring in an audience and it is

22

00:01:05,000 --> 00:01:02,210

alright next month we will have

23

00:01:07,700 --> 00:01:05,010

gravitational wave astronomy which is

24

00:01:09,679 --> 00:01:07,710

now a field something we'd been thinking

25

00:01:13,120 --> 00:01:09,689

about for decades and it's now become a

26

00:01:16,070 --> 00:01:13,130

field our local expert and the fructose

27

00:01:17,330 --> 00:01:16,080

the month after that will feature Fisher

28

00:01:19,910 --> 00:01:17,340

is going to talk about one of my

29

00:01:23,600 --> 00:01:19,920

favorite places in the universe star

30

00:01:25,280 --> 00:01:23,610

formation in the Orion Nebula we're

31

00:01:27,530 --> 00:01:25,290

looking forward to hearing that and then

32

00:01:30,440 --> 00:01:27,540

in July we have one of these really long

33

00:01:33,440 --> 00:01:30,450

titles to call with the Milky Way's

34

00:01:36,770 --> 00:01:33,450

bulge from a hypothesized blob to a

35

00:01:39,859 --> 00:01:36,780

remarkably detailed picture talking

36

00:01:42,260 --> 00:01:39,869

about the center of our galaxy and the

37

00:01:44,300 --> 00:01:42,270

stars that orbit around it out in our

38

00:01:46,700 --> 00:01:44,310

center called the Bulge of our galaxy

39

00:01:49,340 --> 00:01:46,710

okay if you want to learn more about

40

00:01:51,530 --> 00:01:49,350

those or remind yourself of them you can

41

00:01:53,899 --> 00:01:51,540

go to our web page if you go to your

42

00:01:55,520 --> 00:01:53,909

favorite search engine and type in Space

43

00:01:57,649 --> 00:01:55,530

Telescope or Hubble public talks you'll

44

00:02:00,230 --> 00:01:57,659

find this page where we have the list of

45

00:02:03,639 --> 00:02:00,240

the upcoming lectures oops there we go I

46

00:02:06,859 --> 00:02:03,649

think my my lasers it's going all right

47

00:02:10,010 --> 00:02:06,869

we have also on the left-hand side we

48

00:02:11,930 --> 00:02:10,020

have the links for the webcasting both

49

00:02:13,910 --> 00:02:11,940

the Space Telescope webcast II and our

50

00:02:15,949 --> 00:02:13,920

YouTube events the live ones

51
00:02:18,770 --> 00:02:15,959
are active now because it's we're going

52
00:02:23,120 --> 00:02:18,780
live now the archived ones go all the

53
00:02:26,479 --> 00:02:23,130
way back to 2014 on YouTube and 2005 on

54
00:02:28,880 --> 00:02:26,489
the STScl webcast site you can also sign

55
00:02:31,490 --> 00:02:28,890
up for our email list which gets you

56
00:02:36,440 --> 00:02:31,500
about two emails a month reminding you

57
00:02:38,300 --> 00:02:36,450
of the lectures upcoming that email is

58
00:02:40,520 --> 00:02:38,310
on here just sign up at the website and

59
00:02:42,620 --> 00:02:40,530
those of you who can't handle going to a

60
00:02:44,000 --> 00:02:42,630
website can write it down on a piece of

61
00:02:45,800 --> 00:02:44,010
paper and hand it to me at the end of

62
00:02:48,800 --> 00:02:45,810
the lecture and I can make sure you get

63
00:02:50,210 --> 00:02:48,810

on the email list if you have comments

64

00:02:52,759 --> 00:02:50,220

or questions you can send them to the

65

00:02:57,770 --> 00:02:52,769

email address public lecture at STScI

66

00:02:59,420 --> 00:02:57,780

dot edu we have social media for both

67

00:03:01,520 --> 00:02:59,430

the Hubble Space Telescope the Webb

68

00:03:04,400 --> 00:03:01,530

Space Telescope and the Space Telescope

69

00:03:08,420 --> 00:03:04,410

Science Institute on Facebook Twitter

70

00:03:11,240 --> 00:03:08,430

YouTube and Instagram I myself am on

71

00:03:13,520 --> 00:03:11,250

Facebook Google+ and Twitter but don't

72

00:03:17,780 --> 00:03:13,530

expect a lot from me ID I spend a lot of

73

00:03:19,039 --> 00:03:17,790

my time doing other a lot of different

74

00:03:20,590 --> 00:03:19,049

astronomy things that I don't have too

75

00:03:23,750 --> 00:03:20,600

much time to do social media

76

00:03:26,690 --> 00:03:23,760

the observatory across the street will

77

00:03:29,270 --> 00:03:26,700

not be open as you might guess from the

78

00:03:32,840 --> 00:03:29,280

weather outside it's cloudy and a little

79

00:03:34,789 --> 00:03:32,850

bit rainy but they also have open houses

80

00:03:38,449 --> 00:03:34,799

on Friday evenings if you go to their

81

00:03:40,940 --> 00:03:38,459

website MD dot space grant dot o-r-g you

82

00:03:43,190 --> 00:03:40,950

will find that page on the on the right

83

00:03:45,650 --> 00:03:43,200

hand side and in that box that says

84

00:03:48,170 --> 00:03:45,660

Observatory status each Friday evening

85

00:03:49,610 --> 00:03:48,180

by about like 5 or 6 p.m. they post

86

00:03:52,819 --> 00:03:49,620

whether or not they're going to be open

87

00:03:54,199 --> 00:03:52,829

for public observing so yet again we are

88

00:03:57,199 --> 00:03:54,209

unable to take you across the street

89

00:03:59,509 --> 00:03:57,209

after the lecture for that tonight to

90

00:04:02,199 --> 00:03:59,519

the public lecture but hopefully you can

91

00:04:04,819 --> 00:04:02,209

find it on one of the Friday nights and

92

00:04:10,629 --> 00:04:04,829

now our news from the universe for

93

00:04:13,789 --> 00:04:10,639

April 2018 our first story unfortunately

94

00:04:16,610 --> 00:04:13,799

is the James Webb Space Telescope had

95

00:04:18,979 --> 00:04:16,620

another launch delay all right and the

96

00:04:22,510 --> 00:04:18,989

NASA press this is the James Webb Space

97

00:04:26,240 --> 00:04:22,520

Telescope it is a six and a half meter

98

00:04:26,890 --> 00:04:26,250

infrared space telescope that was it's

99

00:04:30,550 --> 00:04:26,900

it's

100

00:04:33,610 --> 00:04:30,560

challenging things we've ever launched

101
00:04:35,590 --> 00:04:33,620
into space possibly the most technically

102
00:04:39,850 --> 00:04:35,600
challenging civilian thing we've ever

103
00:04:41,920 --> 00:04:39,860
launched into space and the NASA press

104
00:04:45,969 --> 00:04:41,930
release stated that the launch window is

105
00:04:48,749 --> 00:04:45,979
now targeted for approximately May 2020

106
00:04:52,260 --> 00:04:48,759
yes we have to wait another year for it

107
00:04:55,390 --> 00:04:52,270
all the observatory but I pulled out

108
00:04:57,610 --> 00:04:55,400
specific quotes all right first of all

109
00:05:00,969 --> 00:04:57,620
all the observatories flight hardware is

110
00:05:02,620 --> 00:05:00,979
now complete okay so if they've got the

111
00:05:04,930 --> 00:05:02,630
spacecraft element and they've got the

112
00:05:06,730 --> 00:05:04,940
telescope element the stuff is complete

113
00:05:09,580 --> 00:05:06,740

and it's all together for the first time

114

00:05:12,189 --> 00:05:09,590

in the Northrop Grumman facility all

115

00:05:13,870 --> 00:05:12,199

right it is undergoing final integration

116

00:05:16,930 --> 00:05:13,880

and test phases that will require more

117

00:05:18,430 --> 00:05:16,940

time to ensure a successful mission we

118

00:05:20,529 --> 00:05:18,440

all remember what happened with the

119

00:05:22,290 --> 00:05:20,539

Hubble Space Telescope having a problem

120

00:05:24,999 --> 00:05:22,300

that needed to be fixed

121

00:05:27,850 --> 00:05:25,009

j2 st is going to be a million miles

122

00:05:29,710 --> 00:05:27,860

from Earth it's not gonna be a low Earth

123

00:05:32,680 --> 00:05:29,720

orbit like Hubble was it cannot be fixed

124

00:05:34,480 --> 00:05:32,690

when it is out there so it is extremely

125

00:05:37,270 --> 00:05:34,490

important to get it right and get it

126

00:05:39,370 --> 00:05:37,280

right the first time as one of the

127

00:05:41,439 --> 00:05:39,380

juniors to engineers says we got to

128

00:05:43,839 --> 00:05:41,449

knock this out of the park a million

129

00:05:45,670 --> 00:05:43,849

miles out of the park all right so yeah

130

00:05:47,740 --> 00:05:45,680

we are taking the time until you to get

131

00:05:50,170 --> 00:05:47,750

it correct and then the other question

132

00:05:52,120 --> 00:05:50,180

people have is about the budget NASA

133

00:05:53,770 --> 00:05:52,130

will provide a new cost estimate that

134

00:05:55,990 --> 00:05:53,780

may exceed the projected 8 billion

135

00:05:58,270 --> 00:05:56,000

development cost to complete the final

136

00:06:00,250 --> 00:05:58,280

phase of testing and prepare for launch

137

00:06:03,250 --> 00:06:00,260

which means that they are currently

138

00:06:05,230 --> 00:06:03,260

evaluating what the delay will cost and

139

00:06:09,520 --> 00:06:05,240

they will provide it to the American

140

00:06:11,230 --> 00:06:09,530

public when they have that okay so it is

141

00:06:13,149 --> 00:06:11,240

still going to do the same great science

142

00:06:16,570 --> 00:06:13,159

we're just gonna have to wait a little

143

00:06:18,129 --> 00:06:16,580

bit longer for it but it is as I said

144

00:06:20,860 --> 00:06:18,139

really important that we get it right

145

00:06:22,740 --> 00:06:20,870

the first time so it's to me it's worth

146

00:06:25,270 --> 00:06:22,750

the extra time ok

147

00:06:29,350 --> 00:06:25,280

second story tonight

148

00:06:34,930 --> 00:06:29,360

planetary construction dust now this

149

00:06:38,080 --> 00:06:34,940

image is up ace of a a disk or actually

150

00:06:39,600 --> 00:06:38,090

a ring around a star that's called HR 47

151
00:06:42,899 --> 00:06:39,610
96 a

152
00:06:46,110 --> 00:06:42,909
okay and it came out in 1999 this is a

153
00:06:48,420 --> 00:06:46,120
Hubble image and I was really excited

154
00:06:50,189 --> 00:06:48,430
when I saw this because I wasn't here at

155
00:06:53,159 --> 00:06:50,199
the time I was up in New York City and

156
00:06:55,469 --> 00:06:53,169
we were discussing the new discoveries

157
00:06:59,270 --> 00:06:55,479
in our own solar system in particular

158
00:07:01,820 --> 00:06:59,280
the Kuiper belt okay this new region of

159
00:07:05,129 --> 00:07:01,830
objects out beyond the orbit of Neptune

160
00:07:07,499 --> 00:07:05,139
all right and this is where Pluto lives

161
00:07:10,860 --> 00:07:07,509
ok Pluto is now the largest member of

162
00:07:12,360 --> 00:07:10,870
the Kuiper belt and so when you look in

163
00:07:14,339 --> 00:07:12,370

the lower right and you see that the

164

00:07:17,700 --> 00:07:14,349

diameter of Neptune's orbit is that and

165

00:07:19,769 --> 00:07:17,710

this ring of material um is just larger

166

00:07:21,480 --> 00:07:19,779

it kind of got us excited because we

167

00:07:23,490 --> 00:07:21,490

were just discovering the Kuiper belt in

168

00:07:26,219 --> 00:07:23,500

our own system and here we were finding

169

00:07:27,809 --> 00:07:26,229

something of the same scale however this

170

00:07:31,830 --> 00:07:27,819

isn't the Kuiper belt okay it's not made

171

00:07:34,260 --> 00:07:31,840

of ice this is made of dust and it's you

172

00:07:35,490 --> 00:07:34,270

don't even expect it to be a fully

173

00:07:40,409 --> 00:07:35,500

formed Kuiper belt type thing because

174

00:07:45,029 --> 00:07:40,419

the star HR 47 96 a is only 8 million

175

00:07:47,760 --> 00:07:45,039

years old but at 8 million years that's

176

00:07:48,469 --> 00:07:47,770

the time scale on which giant planets

177

00:07:54,540 --> 00:07:48,479

form

178

00:07:57,079 --> 00:07:54,550

order 10 million years so seeing a dust

179

00:08:01,200 --> 00:07:57,089

ring that's so tightly correlated here

180

00:08:03,269 --> 00:08:01,210

could indicate that a giant planet had

181

00:08:05,670 --> 00:08:03,279

formed in this system has recently

182

00:08:09,029 --> 00:08:05,680

formed in this system and that makes is

183

00:08:11,730 --> 00:08:09,039

exciting now so we can take this image

184

00:08:14,129 --> 00:08:11,740

we're gonna shrink it and rotate it okay

185

00:08:17,670 --> 00:08:14,139

that's the exact same image okay and now

186

00:08:22,290 --> 00:08:17,680

we have a new image of HR 47 96 a that

187

00:08:25,079 --> 00:08:22,300

looks like that yeah more sensitive

188

00:08:27,990 --> 00:08:25,089

looking deeper and seeing dust not in

189

00:08:32,550 --> 00:08:28,000

just a tight ring but actually spread

190

00:08:35,819 --> 00:08:32,560

out across the system see 47 96 a is

191

00:08:39,060 --> 00:08:35,829

about 23 times more luminous than the

192

00:08:42,300 --> 00:08:39,070

Sun right so therefore it has a lot more

193

00:08:44,420 --> 00:08:42,310

radiation pressure and so while giant

194

00:08:47,760 --> 00:08:44,430

planets formed on order 10 million years

195

00:08:50,250 --> 00:08:47,770

planets like Earth form on timescales of

196

00:08:53,130 --> 00:08:50,260

a hundred million years and in the

197

00:08:55,530 --> 00:08:53,140

process of building up tourists

198

00:08:56,750 --> 00:08:55,540

planets you get a lot of things smashing

199

00:08:59,160 --> 00:08:56,760

together all right

200

00:09:01,230 --> 00:08:59,170

planetesimals accretion and that

201
00:09:03,870 --> 00:09:01,240
produces some dust right planetary

202
00:09:08,130 --> 00:09:03,880
construction dust and the radiation

203
00:09:10,259 --> 00:09:08,140
pressure from 47 96 a can actually blow

204
00:09:12,780 --> 00:09:10,269
some of that dust out of the system like

205
00:09:15,569 --> 00:09:12,790
this alright so the interpretation of

206
00:09:18,389 --> 00:09:15,579
this image is that some of this dust is

207
00:09:20,340 --> 00:09:18,399
coming from the form possibly coming or

208
00:09:22,410 --> 00:09:20,350
as a reasonable hypothesis is that it's

209
00:09:24,300 --> 00:09:22,420
coming from the formation of terrestrial

210
00:09:26,100 --> 00:09:24,310
planets that's kicking up dust and then

211
00:09:29,940 --> 00:09:26,110
being pushed out by the radiation

212
00:09:32,639 --> 00:09:29,950
pressure of this large star spreading it

213
00:09:35,220 --> 00:09:32,649

across the system so that's kind of cool

214

00:09:39,120 --> 00:09:35,230

and here is by the way all of the

215

00:09:40,740 --> 00:09:39,130

details of this so 47 96 a is in that

216

00:09:42,750 --> 00:09:40,750

dark spot there we block it out of

217

00:09:44,940 --> 00:09:42,760

course because if you have the star you

218

00:09:47,519 --> 00:09:44,950

can't see the dust around it you can see

219

00:09:49,800 --> 00:09:47,529

the the ring there's also you notice a

220

00:09:52,560 --> 00:09:49,810

bow shock that curved line because the

221

00:09:55,170 --> 00:09:52,570

star system is moving through medium so

222

00:09:57,180 --> 00:09:55,180

you get a thing and also in the lower

223

00:10:01,199 --> 00:09:57,190

right there's a dark circle there that

224

00:10:03,030 --> 00:10:01,209

is the companion star 47 96 B all right

225

00:10:04,380 --> 00:10:03,040

and actually I what I think is kind of

226

00:10:05,100 --> 00:10:04,390

cool which we didn't mark is in the

227

00:10:09,509 --> 00:10:05,110

lower left

228

00:10:11,130 --> 00:10:09,519

that's a background galaxy so we're

229

00:10:12,660 --> 00:10:11,140

looking at a star in our galaxy but

230

00:10:14,519 --> 00:10:12,670

we're also looking at a background

231

00:10:17,220 --> 00:10:14,529

galaxy in the same image here

232

00:10:19,560 --> 00:10:17,230

alright so we're this may be the dust

233

00:10:23,670 --> 00:10:19,570

kicked up by the construction of planets

234

00:10:27,660 --> 00:10:23,680

in another solar system final story a

235

00:10:29,460 --> 00:10:27,670

cosmology conundrum about a hundred

236

00:10:31,740 --> 00:10:29,470

years ago a little less than a hundred

237

00:10:34,680 --> 00:10:31,750

years ago Edwin Hubble made this diagram

238

00:10:37,650 --> 00:10:34,690

and on this diagram he's plotting galaxy

239

00:10:39,509 --> 00:10:37,660

distance against galaxy redshift and he

240

00:10:41,490 --> 00:10:39,519

found he got a straight line that

241

00:10:43,769 --> 00:10:41,500

galaxies that were further away had

242

00:10:46,620 --> 00:10:43,779

larger redshifts in a linear fashion and

243

00:10:49,230 --> 00:10:46,630

this is the primary motivating evidence

244

00:10:51,180 --> 00:10:49,240

for the expanding universe all right

245

00:10:53,130 --> 00:10:51,190

that space is expanding and therefore

246

00:10:56,069 --> 00:10:53,140

distant galaxies appear to be moving

247

00:10:59,639 --> 00:10:56,079

away faster in a linear fashion

248

00:11:01,050 --> 00:10:59,649

however the slope of it is the expansion

249

00:11:02,730 --> 00:11:01,060

rate of the universe the current

250

00:11:05,460 --> 00:11:02,740

expansion rate of the universe we call

251

00:11:06,600 --> 00:11:05,470

that the Hubble constant unfortunately

252

00:11:08,790 --> 00:11:06,610

he got the Hubble constant

253

00:11:10,920 --> 00:11:08,800

wrong because the way he was measuring

254

00:11:12,420 --> 00:11:10,930

distances depended on Cepheid

255

00:11:14,190 --> 00:11:12,430

variables and he was using the wrong

256

00:11:16,769 --> 00:11:14,200

type of Cepheid variables so he got it

257

00:11:19,050 --> 00:11:16,779

wrong by about a factor of 10 but

258

00:11:23,100 --> 00:11:19,060

eventually we astronomers got it right

259

00:11:25,380 --> 00:11:23,110

so this plot shows a date on the x-axis

260

00:11:27,420 --> 00:11:25,390

and the value of H_0 which is this

261

00:11:29,040 --> 00:11:27,430

Hubble constant starts out in the

262

00:11:31,110 --> 00:11:29,050

hundreds and then finally gets down to

263

00:11:33,900 --> 00:11:31,120

when I was in graduate school

264

00:11:37,019 --> 00:11:33,910

in the late 80s the values were between

265

00:11:38,550 --> 00:11:37,029

50 and 100 so yeah we went from being a

266

00:11:41,100 --> 00:11:38,560

factor of 10 off to being down to a

267

00:11:43,050 --> 00:11:41,110

factor of 2 and this is cosmology a

268

00:11:44,670 --> 00:11:43,060

factor of 2 is good all right I keep

269

00:11:46,730 --> 00:11:44,680

telling myself I'm an astronomer a

270

00:11:51,000 --> 00:11:46,740

factor of 2 is good enough for me right

271

00:11:52,560 --> 00:11:51,010

and so but that's still not good enough

272

00:11:55,620 --> 00:11:52,570

to do what we call precision cosmology

273

00:11:58,590 --> 00:11:55,630

so when the hubble space telescope came

274

00:12:00,720 --> 00:11:58,600

online one of its key projects was

275

00:12:03,750 --> 00:12:00,730

measuring the Hubble constant by getting

276

00:12:05,460 --> 00:12:03,760

accurate distances to near near galaxies

277

00:12:08,220 --> 00:12:05,470

so that we could really measure the

278

00:12:12,990 --> 00:12:08,230

Hubble constant carefully as an HST key

279

00:12:15,930 --> 00:12:13,000

project in the year 2000 that the data

280

00:12:19,079 --> 00:12:15,940

was released and this is a graphic of

281

00:12:21,389 --> 00:12:19,089

the diagram showing that here the points

282

00:12:25,590 --> 00:12:21,399

plotted and plausible values were

283

00:12:27,269 --> 00:12:25,600

between 63 and 77 so that's great we've

284

00:12:28,680 --> 00:12:27,279

you know it's gone from you know being a

285

00:12:33,210 --> 00:12:28,690

factor of 10 off to down to a factor of

286

00:12:36,060 --> 00:12:33,220

2 down to 10% okay we had a difference

287

00:12:38,340 --> 00:12:36,070

of 10% but can we leave that alone

288

00:12:40,500 --> 00:12:38,350

no we're scientists we really want to

289

00:12:42,780 --> 00:12:40,510

beat that down and beat that down so

290

00:12:44,699 --> 00:12:42,790

what they have done with Hubble recently

291

00:12:48,300 --> 00:12:44,709

is they went back and remeasure the

292

00:12:51,569 --> 00:12:48,310

Cepheid in our galaxy the calibration

293

00:12:53,970 --> 00:12:51,579

method as well as doing other things and

294

00:12:57,870 --> 00:12:53,980

we are able in this new paper that just

295

00:13:02,189 --> 00:12:57,880

came out get it down to a range of 72 to

296

00:13:07,270 --> 00:13:02,199

75 success we finally have this Hubble

297

00:13:10,390 --> 00:13:07,280

constant measured except

298

00:13:13,450 --> 00:13:10,400

in the meantime we have developed other

299

00:13:15,940 --> 00:13:13,460

ways estimating the Hubble constant one

300

00:13:18,040 --> 00:13:15,950

of them depends upon measuring the

301
00:13:20,140 --> 00:13:18,050
Cosmic Microwave Background this is the

302
00:13:22,030 --> 00:13:20,150
Coby satellite the first measurement of

303
00:13:24,310 --> 00:13:22,040
the cosmic wave background which then

304
00:13:25,930 --> 00:13:24,320
got refined with the W map satellite and

305
00:13:28,300 --> 00:13:25,940
then got improved as to still a little

306
00:13:31,030 --> 00:13:28,310
bit more with the Planck satellite and

307
00:13:33,190 --> 00:13:31,040
this is measuring the temperature

308
00:13:34,510 --> 00:13:33,200
differences which is basically the

309
00:13:37,390 --> 00:13:34,520
density differences in the early

310
00:13:38,800 --> 00:13:37,400
universe and from that what we really

311
00:13:39,760 --> 00:13:38,810
measure out of the the COTS microwave

312
00:13:42,550 --> 00:13:39,770
background is something we call the

313
00:13:45,100 --> 00:13:42,560

power spectrum which is how much density

314

00:13:47,980 --> 00:13:45,110

is on different scales in the early

315

00:13:49,630 --> 00:13:47,990

universe and from that you know we can

316

00:13:51,040 --> 00:13:49,640

extrapolate through to the rest of the

317

00:13:54,460 --> 00:13:51,050

universe and start figuring out the

318

00:13:57,400 --> 00:13:54,470

expansion rate in particular the second

319

00:14:00,010 --> 00:13:57,410

peak of this power spectrum is sensitive

320

00:14:03,100 --> 00:14:00,020

to the hubble value the expansion rate

321

00:14:05,500 --> 00:14:03,110

of the universe okay and so its location

322

00:14:07,600 --> 00:14:05,510

and its its magnitude gives us a good

323

00:14:09,250 --> 00:14:07,610

estimate of the Hubble constant it

324

00:14:11,530 --> 00:14:09,260

doesn't give us a perfect estimate but

325

00:14:13,660 --> 00:14:11,540

it gives us a good estimate combine that

326
00:14:16,150 --> 00:14:13,670
with two other ways of measuring things

327
00:14:18,460 --> 00:14:16,160
one from supernovae and one from

328
00:14:21,970 --> 00:14:18,470
something called baryon acoustic

329
00:14:24,280 --> 00:14:21,980
oscillations it's labeled Bao I'm not

330
00:14:26,790 --> 00:14:24,290
gonna try and explain that in 30 seconds

331
00:14:29,320 --> 00:14:26,800
here it doesn't work but trust me

332
00:14:30,550 --> 00:14:29,330
combining the three of them the Cosmic

333
00:14:33,520 --> 00:14:30,560
Microwave Background baryon acoustic

334
00:14:35,860 --> 00:14:33,530
oscillations and the supernovae you can

335
00:14:38,650 --> 00:14:35,870
get another estimate of the Hubble

336
00:14:40,600 --> 00:14:38,660
constant independent of the Cepheid

337
00:14:46,810 --> 00:14:40,610
variables and all that and it comes out

338
00:14:49,240 --> 00:14:46,820

to 65 to 69 here's the problem both of

339

00:14:51,430 --> 00:14:49,250

these methods are tried-and-true both of

340

00:14:53,950 --> 00:14:51,440

these methods are we believe are

341

00:14:57,160 --> 00:14:53,960

estimating their errors well all right

342

00:15:00,370 --> 00:14:57,170

the local ones 72 to 75 the large-scale

343

00:15:01,780 --> 00:15:00,380

ones 65 to 69 and the quote from Adam

344

00:15:03,670 --> 00:15:01,790

riess the head of the researcher says

345

00:15:06,579 --> 00:15:03,680

both results have been tested multiple

346

00:15:09,310 --> 00:15:06,589

ways so barring a series of unrelated

347

00:15:11,920 --> 00:15:09,320

mistakes it is increasingly likely that

348

00:15:14,560 --> 00:15:11,930

this is not a bug but a feature of the

349

00:15:16,390 --> 00:15:14,570

universe that are local estimates of the

350

00:15:18,490 --> 00:15:16,400

Hubble value Hubble constant value

351

00:15:20,830 --> 00:15:18,500

differ from our large-scale measure

352

00:15:24,220 --> 00:15:20,840

estimates of the Hubble value

353

00:15:26,320 --> 00:15:24,230

what do we do okay well if you read the

354

00:15:29,230 --> 00:15:26,330

news bag news news about this

355

00:15:30,010 --> 00:15:29,240

astronomers are baffled no we're not

356

00:15:33,360 --> 00:15:30,020

baffled okay

357

00:15:35,500 --> 00:15:33,370

we're intrigued we're excited because

358

00:15:38,020 --> 00:15:35,510

frankly if we knew everything we'd be

359

00:15:39,790 --> 00:15:38,030

out of a job so this gives us something

360

00:15:42,610 --> 00:15:39,800

new there's something new in the

361

00:15:44,770 --> 00:15:42,620

universe it's either our problem which

362

00:15:46,210 --> 00:15:44,780

it's unlikely or there's some new

363

00:15:47,890 --> 00:15:46,220

feature in the universe okay

364

00:15:50,740 --> 00:15:47,900

so of course we can come up with new

365

00:15:52,570 --> 00:15:50,750

ideas and so some of the new ideas are

366

00:15:56,710 --> 00:15:52,580

perhaps there is an undiscovered

367

00:16:00,970 --> 00:15:56,720

subatomic particle such as a neutrino

368

00:16:02,440 --> 00:16:00,980

with mass that changes the measurements

369

00:16:03,670 --> 00:16:02,450

that we would get from one of the one of

370

00:16:07,150 --> 00:16:03,680

these values basically that would be a

371

00:16:09,280 --> 00:16:07,160

large scale or maybe dark matter doesn't

372

00:16:10,630 --> 00:16:09,290

behave exactly the way we think it is we

373

00:16:12,400 --> 00:16:10,640

think Dark Matter only behaves

374

00:16:14,710 --> 00:16:12,410

gravitationally maybe there's a little

375

00:16:17,740 --> 00:16:14,720

bit stronger interaction between dark

376

00:16:19,810 --> 00:16:17,750

matter and normal matter or the most

377

00:16:21,640 --> 00:16:19,820

popular one that you can written

378

00:16:23,410 --> 00:16:21,650

thinking today is what about dark energy

379

00:16:25,750 --> 00:16:23,420

we don't know much about dark energy

380

00:16:27,730 --> 00:16:25,760

we've got a lot of ignorance there maybe

381

00:16:30,160 --> 00:16:27,740

some of that ignorant effects one of

382

00:16:33,100 --> 00:16:30,170

these measures okay so we have a lot of

383

00:16:35,710 --> 00:16:33,110

hypotheses and ideas on what might

384

00:16:39,040 --> 00:16:35,720

resolve this but also I can really say

385

00:16:42,370 --> 00:16:39,050

is stay tuned because we have identified

386

00:16:44,080 --> 00:16:42,380

a discrepancy all right and the process

387

00:16:45,370 --> 00:16:44,090

of science is we're gonna hack at it and

388

00:16:47,290 --> 00:16:45,380

we're gonna hack at it we're gonna hack

389

00:16:49,870 --> 00:16:47,300

at it until either we figure out what's

390

00:16:51,670 --> 00:16:49,880

wrong with our observations or we come

391

00:16:53,830 --> 00:16:51,680

up with a really good idea that can

392

00:16:55,540 --> 00:16:53,840

explain this discrepancy and to me

393

00:16:57,730 --> 00:16:55,550

that's part of the joy and excitement of

394

00:16:58,830 --> 00:16:57,740

science when you find something that you

395

00:17:01,450 --> 00:16:58,840

can't explain

396

00:17:03,640 --> 00:17:01,460

then you're just like oh we got to

397

00:17:05,980 --> 00:17:03,650

figure this out unfortunately it'll take

398

00:17:08,080 --> 00:17:05,990

a decade or two that's actually find out

399

00:17:09,370 --> 00:17:08,090

so stay tuned and keep coming to the

400

00:17:11,770 --> 00:17:09,380

public lecture series I'll make sure

401
00:17:15,150 --> 00:17:11,780
that I have it for you all right okay

402
00:17:19,060 --> 00:17:15,160
and that's our news from the universe

403
00:17:22,150 --> 00:17:19,070
our featured speaker tonight is Susanna

404
00:17:25,090 --> 00:17:22,160
de use to ax she has been here for what

405
00:17:28,330 --> 00:17:25,100
10 years and she works in the AI NS

406
00:17:30,730 --> 00:17:28,340
division on the Hubble instrument Wide

407
00:17:34,240 --> 00:17:30,740
Field Camera 3 or we just call it with

408
00:17:35,890 --> 00:17:34,250
c3 and

409
00:17:37,810 --> 00:17:35,900
I asked her for some interesting things

410
00:17:42,270 --> 00:17:37,820
about her and she said that she fly

411
00:17:44,260 --> 00:17:42,280
Fitch's fly fishes from her kayak

412
00:17:48,310 --> 00:17:44,270
combining kayaking and fly fishing

413
00:17:50,950 --> 00:17:48,320

together and that once she did jump out

414

00:17:54,130 --> 00:17:50,960

of an airplane even as well as having

415

00:17:56,890 --> 00:17:54,140

never been on the Space Shuttle okay so

416

00:18:07,730 --> 00:17:56,900

here to tell us about Jupiter's moon

417

00:18:12,630 --> 00:18:07,740

Europa is Susanna Deus Troy thank you

418

00:18:29,260 --> 00:18:16,390

and I think I'm number one or three

419

00:18:31,270 --> 00:18:29,270

maybe I'm three okay all right so we're

420

00:18:48,490 --> 00:18:31,280

going to talk a little bit about the

421

00:19:07,130 --> 00:18:51,380

it recalibrated after I disconnected

422

00:19:07,140 --> 00:19:11,540

somebody needs to sing the jeopardy tune

423

00:19:15,300 --> 00:19:12,750

okay

424

00:19:19,590 --> 00:19:15,310

so with any luck I'll be able to tell

425

00:19:24,510 --> 00:19:19,600

you a little something about the plumes

426

00:19:26,190 --> 00:19:24,520

on Europa water ice life which is a

427

00:19:32,190 --> 00:19:26,200

little bit like our Baltimore winter

428

00:19:34,890 --> 00:19:32,200

this year let's see which way does this

429

00:19:39,780 --> 00:19:34,900

go so this is the abstract that I put

430

00:19:43,730 --> 00:19:39,790

together but more importantly is there

431

00:19:45,690 --> 00:19:43,740

are lots of people working on

432

00:19:49,080 --> 00:19:45,700

understanding what's going on with

433

00:19:52,890 --> 00:19:49,090

Europa in advance of perhaps actually

434

00:19:54,210 --> 00:19:52,900

sending a dedicated mission and I was

435

00:19:56,580 --> 00:19:54,220

trying to play around to figure but this

436

00:19:58,110 --> 00:19:56,590

was team a or team B or the raw team or

437

00:20:00,030 --> 00:19:58,120

the sparks team and I gave up on that

438

00:20:03,510 --> 00:20:00,040

because people go back and forth and

439

00:20:05,400 --> 00:20:03,520

people talk to each other so there I'm

440

00:20:08,480 --> 00:20:05,410

sure that I laughs I inadvertently might

441

00:20:11,820 --> 00:20:08,490

have left off some people but I

442

00:20:15,480 --> 00:20:11,830

apologize if I did that so more

443

00:20:18,240 --> 00:20:15,490

importantly is as an observer probably

444

00:20:20,310 --> 00:20:18,250

not tonight but maybe when it's clear if

445

00:20:22,650 --> 00:20:20,320

you go out and they look in the

446

00:20:26,280 --> 00:20:22,660

southeast kind of find where the moon is

447

00:20:28,620 --> 00:20:26,290

and you will see Jupiter and so

448

00:20:31,430 --> 00:20:28,630

Jupiter's a planet as you all know that

449

00:20:34,590 --> 00:20:31,440

we've known since antiquity when our

450

00:20:36,750 --> 00:20:34,600

ancestors first became Homo sapiens I am

451
00:20:45,080 --> 00:20:36,760
sure they looked up and saw Jupiter and

452
00:20:49,920 --> 00:20:45,090
named it something and 400 years ago in

453
00:20:51,930 --> 00:20:49,930
1609 Galileo as we know in I wouldn't

454
00:20:54,440 --> 00:20:51,940
say he invented the telescope but he was

455
00:20:56,970 --> 00:20:54,450
one of the first to put it together and

456
00:20:59,760 --> 00:20:56,980
incidentally he was very ill he had like

457
00:21:01,200 --> 00:20:59,770
the flu or something when he was putting

458
00:21:03,870 --> 00:21:01,210
together at the telescope

459
00:21:07,470 --> 00:21:03,880
I guess he kept him from being too sick

460
00:21:11,910 --> 00:21:07,480
and later he turned that telescope and

461
00:21:13,590 --> 00:21:11,920
he was the first to point at a celestial

462
00:21:15,790 --> 00:21:13,600
object and in his case it was Jupiter

463
00:21:20,110 --> 00:21:15,800

and what he saw over

464

00:21:24,600 --> 00:21:20,120

a period of time were a series of moons

465

00:21:27,820 --> 00:21:24,610

or objects or little stars that were

466

00:21:29,650 --> 00:21:27,830

revolving or moving around Jupiter and

467

00:21:31,780 --> 00:21:29,660

this is just a blow-up of that letter

468

00:21:36,340 --> 00:21:31,790

that I showed which is a letter he wrote

469

00:21:39,070 --> 00:21:36,350

to the Doge a of Venice in 1610 and he

470

00:21:44,620 --> 00:21:39,080

in that letter he is describing his

471

00:21:50,890 --> 00:21:44,630

observations so 1609 first observations

472

00:21:52,930 --> 00:21:50,900

of Europa and if I can do this I will

473

00:21:58,720 --> 00:21:52,940

start the movie because this is kind of

474

00:22:02,110 --> 00:21:58,730

cute I love the Internet this is a movie

475

00:22:04,990 --> 00:22:02,120

that put together by a gentleman named I

476

00:22:07,720 --> 00:22:05,000

think somebody right he has a website

477

00:22:10,840 --> 00:22:07,730

he's a computer scientist by profession

478

00:22:13,870 --> 00:22:10,850

and what he did is he took all of the

479

00:22:17,620 --> 00:22:13,880

observations that Galileo had recorded

480

00:22:20,860 --> 00:22:17,630

and he's juxtaposed those on a on the

481

00:22:23,440 --> 00:22:20,870

ephemeris and so what you see now is the

482

00:22:25,450 --> 00:22:23,450

beautiful pictures on the top and then

483

00:22:26,890 --> 00:22:25,460

Galileo's observations on the bottom

484

00:22:31,990 --> 00:22:26,900

this is just sort of a fun little thing

485

00:22:36,190 --> 00:22:32,000

and it'll go through sort of the modern

486

00:22:39,250 --> 00:22:36,200

and the end the ancient ok so let's just

487

00:22:42,430 --> 00:22:39,260

put this in context a little bit when we

488

00:22:44,350 --> 00:22:42,440

talk about the moons it's you know it's

489

00:22:47,530 --> 00:22:44,360

natural to think of it as being like our

490

00:22:50,710 --> 00:22:47,540

moon so here's our moon here this is

491

00:22:53,320 --> 00:22:50,720

Europa and it's about the same size over

492

00:22:55,540 --> 00:22:53,330

here so that's kind of comforting Moon's

493

00:22:59,850 --> 00:22:55,550

can be the same size as our Moon this is

494

00:23:02,320 --> 00:22:59,860

Callisto Ganymede Europa and IO or IO

495

00:23:04,600 --> 00:23:02,330

the four Galilean moons of although

496

00:23:06,070 --> 00:23:04,610

Galileo called and the Medici moons as

497

00:23:10,270 --> 00:23:06,080

you remember because the Medici was

498

00:23:13,900 --> 00:23:10,280

where his patrons it's always good to

499

00:23:17,350 --> 00:23:13,910

keep your patrons happy anyway so here's

500

00:23:19,030 --> 00:23:17,360

Europa tis not the largest of Jupiter's

501
00:23:21,250 --> 00:23:19,040
moons but it is certainly one of the

502
00:23:23,020 --> 00:23:21,260
most interesting along with you and neo

503
00:23:25,840 --> 00:23:23,030
is known to have volcanic activity and

504
00:23:27,730 --> 00:23:25,850
just for fun and scale here's one of the

505
00:23:29,230 --> 00:23:27,740
bands on Jupiter so you get the sense

506
00:23:29,620 --> 00:23:29,240
that these are actually relatively small

507
00:23:34,720 --> 00:23:29,630
and

508
00:23:36,490 --> 00:23:34,730
jupiter is very very big so we will skip

509
00:23:39,400 --> 00:23:36,500
forward a few hundred years to the

510
00:23:43,150 --> 00:23:39,410
Voyager missions and the Voyager I think

511
00:23:46,470 --> 00:23:43,160
are the most successful missions in my

512
00:23:50,320 --> 00:23:46,480
view that NASA has put together they

513
00:23:52,900 --> 00:23:50,330

have been going through the solar system

514

00:23:55,180 --> 00:23:52,910

for over 30 approaching 40 years

515

00:23:58,030 --> 00:23:55,190

returning good data ever since and it

516

00:24:00,910 --> 00:23:58,040

this was one of the first images that we

517

00:24:03,820 --> 00:24:00,920

had close-up images that we had of

518

00:24:06,450 --> 00:24:03,830

Jupiter and its moons this over here is

519

00:24:08,680 --> 00:24:06,460

a o and this is Europa down here

520

00:24:10,990 --> 00:24:08,690

question and these little dots are just

521

00:24:14,260 --> 00:24:11,000

some fiducial marks on the imaging

522

00:24:16,450 --> 00:24:14,270

system of Voyager about 20 years later

523

00:24:18,460 --> 00:24:16,460

there was another mission this time

524

00:24:22,150 --> 00:24:18,470

called the Galileo mission which also

525

00:24:24,040 --> 00:24:22,160

went to Jupiter and what I think is

526

00:24:27,580 --> 00:24:24,050

remarkable and a lot of people have as

527

00:24:30,160 --> 00:24:27,590

well is that we see Europa this was

528

00:24:34,240 --> 00:24:30,170

taken about I don't know almost six

529

00:24:36,130 --> 00:24:34,250

sixty thousand miles away is that Europe

530

00:24:37,780 --> 00:24:36,140

is relatively smooth it doesn't have big

531

00:24:39,360 --> 00:24:37,790

huge craters it doesn't have big huge

532

00:24:42,220 --> 00:24:39,370

mountains and it's got all these little

533

00:24:45,570 --> 00:24:42,230

striations all over it and some dark

534

00:24:47,980 --> 00:24:45,580

spots so it's a very interesting moon

535

00:24:50,740 --> 00:24:47,990

it's an interesting object in and of

536

00:24:53,920 --> 00:24:50,750

itself and this is a beautiful image

537

00:24:58,770 --> 00:24:53,930

that got reprocessed in the imaging

538

00:25:03,250 --> 00:24:58,780

department by somebody so to highlight

539

00:25:05,710 --> 00:25:03,260

the striations and sort of false color

540

00:25:09,520 --> 00:25:05,720

images and what you see is that these

541

00:25:13,360 --> 00:25:09,530

look like cracks in the ice fissures in

542

00:25:17,290 --> 00:25:13,370

the ice which tells you something about

543

00:25:19,720 --> 00:25:17,300

what is going on in on the moon and this

544

00:25:22,720 --> 00:25:19,730

is a blow-up also from the Galileo

545

00:25:25,270 --> 00:25:22,730

spacecraft where you can see these

546

00:25:27,790 --> 00:25:25,280

cracks and fissures and apparently some

547

00:25:28,990 --> 00:25:27,800

deposits of material because it's not

548

00:25:33,430 --> 00:25:29,000

all white and icy

549

00:25:35,560 --> 00:25:33,440

so this points to and there been a lot

550

00:25:38,590 --> 00:25:35,570

of papers and people got really busy and

551
00:25:42,740 --> 00:25:38,600
said this this looks a lot like cracking

552
00:25:44,660 --> 00:25:42,750
of ice and maybe it looks like looks

553
00:25:48,050 --> 00:25:44,670
like plate tectonics like we have on

554
00:25:50,240 --> 00:25:48,060
earth the the continental crusts and our

555
00:25:53,120 --> 00:25:50,250
shifting around in subducting and

556
00:25:57,110 --> 00:25:53,130
separating in this case this is on the

557
00:26:00,890 --> 00:25:57,120
icy surface so it's a very very

558
00:26:02,990 --> 00:26:00,900
intriguing but in addition one of the

559
00:26:05,300 --> 00:26:03,000
things that the Galileo spacecraft had

560
00:26:06,980 --> 00:26:05,310
with it was a magnetometer so it was

561
00:26:11,360 --> 00:26:06,990
measuring the magnetic field around

562
00:26:15,070 --> 00:26:11,370
Jupiter and an interesting thing is that

563
00:26:17,420 --> 00:26:15,080

if you have another source of

564

00:26:19,220 --> 00:26:17,430

electromagnetism it's sort of like

565

00:26:20,840 --> 00:26:19,230

having two magnets if you try to put the

566

00:26:24,110 --> 00:26:20,850

two South Poles together you get a

567

00:26:26,420 --> 00:26:24,120

little deflection have you ever tried

568

00:26:28,130 --> 00:26:26,430

that when you were kids so you'd see

569

00:26:29,630 --> 00:26:28,140

something similar if you had another

570

00:26:31,550 --> 00:26:29,640

source nearby you would see a little

571

00:26:34,330 --> 00:26:31,560

deflection in the magnetic field

572

00:26:36,320 --> 00:26:34,340

so when gyro PI was passing through

573

00:26:40,780 --> 00:26:36,330

Jupiter's magnetic field the

574

00:26:43,910 --> 00:26:40,790

magnetometer detected a deflection and

575

00:26:46,100 --> 00:26:43,920

that deflection was consistent with it

576
00:26:48,500 --> 00:26:46,110
another conductive or an inductive body

577
00:26:52,790 --> 00:26:48,510
and it probably had to be something like

578
00:26:55,100 --> 00:26:52,800
slushy salty water because it had to be

579
00:26:56,720 --> 00:26:55,110
something that was globally connected he

580
00:26:58,880 --> 00:26:56,730
couldn't just have one little pond it

581
00:27:00,440 --> 00:26:58,890
had to be all all around and about the

582
00:27:06,260 --> 00:27:00,450
only thing people could think of at the

583
00:27:08,180 --> 00:27:06,270
time was some slushy icy material which

584
00:27:11,750 --> 00:27:08,190
of course makes things really really

585
00:27:14,900 --> 00:27:11,760
interesting because now we have ice on

586
00:27:21,350 --> 00:27:14,910
this planet and potentially also water

587
00:27:23,150 --> 00:27:21,360
and so this is a sort of a model of what

588
00:27:25,340 --> 00:27:23,160

this might look like here's the the

589

00:27:28,010 --> 00:27:25,350

water down here some kind of a thick

590

00:27:31,580 --> 00:27:28,020

warm ice shelf and here you can see the

591

00:27:34,340 --> 00:27:31,590

cracks on the top subducting just like

592

00:27:36,650 --> 00:27:34,350

they would on on earth Stevie had plate

593

00:27:39,350 --> 00:27:36,660

tectonics and we're there little soft

594

00:27:41,120 --> 00:27:39,360

spots you might see sort of cryo lavas

595

00:27:45,110 --> 00:27:41,130

so instead of being molten lava I would

596

00:27:48,440 --> 00:27:45,120

be molten water otherwise known as

597

00:27:50,510 --> 00:27:48,450

liquid water and this would be something

598

00:27:52,430 --> 00:27:50,520

that would build up over time and the

599

00:27:54,530 --> 00:27:52,440

other clue to this is that was because

600

00:27:56,150 --> 00:27:54,540

the surface of Europe is so smooth it

601
00:27:58,370 --> 00:27:56,160
doesn't have a lot of cratering what

602
00:28:00,170 --> 00:27:58,380
also indicates it's a young surface and

603
00:28:02,210 --> 00:28:00,180
the only way you get a young surface is

604
00:28:04,490 --> 00:28:02,220
if you have some regeneration of

605
00:28:08,660 --> 00:28:04,500
material that covers the cracks and the

606
00:28:10,160 --> 00:28:08,670
in the craters so this is all pretty

607
00:28:14,210 --> 00:28:10,170
fascinating and people got really

608
00:28:15,890 --> 00:28:14,220
intrigued but this wasn't really enough

609
00:28:20,180 --> 00:28:15,900
to answer the question because you could

610
00:28:25,700 --> 00:28:20,190
still imagine having a rocky core in the

611
00:28:30,470 --> 00:28:25,710
planet ice warm ice and then cold ice on

612
00:28:34,880 --> 00:28:30,480
the surface or maybe you had a rocky

613
00:28:39,080 --> 00:28:34,890

interior and then a water layer down

614

00:28:41,660 --> 00:28:39,090

here and then ice and this was something

615

00:28:44,030 --> 00:28:41,670

in play if you have a lot of ice it's

616

00:28:47,210 --> 00:28:44,040

probably not so interesting or maybe it

617

00:28:49,610 --> 00:28:47,220

is but if you have water now you start

618

00:28:51,830 --> 00:28:49,620

thinking could you possibly have

619

00:28:56,510 --> 00:28:51,840

something really interesting going on if

620

00:28:57,980 --> 00:28:56,520

you have water and the answer of course

621

00:29:00,560 --> 00:28:57,990

and what we're working up to is if you

622

00:29:02,780 --> 00:29:00,570

have water then you have life or you

623

00:29:07,310 --> 00:29:02,790

have the possibility of life but the one

624

00:29:10,850 --> 00:29:07,320

question is Europa is far away it's very

625

00:29:13,570 --> 00:29:10,860

far from from the Sun it's and you have

626

00:29:17,750 --> 00:29:13,580

this icy cover so how would you get

627

00:29:21,320 --> 00:29:17,760

heating of the material to in order to

628

00:29:23,330 --> 00:29:21,330

have a liquid water ocean and so one

629

00:29:25,370 --> 00:29:23,340

potential answer and this is probably

630

00:29:28,760 --> 00:29:25,380

the right one is something called tidal

631

00:29:32,060 --> 00:29:28,770

heating and what that does is as as as

632

00:29:33,920 --> 00:29:32,070

Europa goes around Jupiter it's not in a

633

00:29:37,820 --> 00:29:33,930

perfectly circular orbit so you have

634

00:29:39,920 --> 00:29:37,830

gravitational forces acting on the moon

635

00:29:41,420 --> 00:29:39,930

itself sort of pushing and pulling it

636

00:29:43,490 --> 00:29:41,430

you can think of it as either you know

637

00:29:45,230 --> 00:29:43,500

and you bend a spoon you get a little

638

00:29:47,690 --> 00:29:45,240

heat or you're stretching a rubber band

639

00:29:49,730 --> 00:29:47,700

and you feel it it gets a little hot so

640

00:29:52,930 --> 00:29:49,740

sort of like friction and that is

641

00:30:01,790 --> 00:29:52,940

probably the source of the heat that

642

00:30:03,950 --> 00:30:01,800

keeps the water liquid then the Galileo

643

00:30:07,010 --> 00:30:03,960

mission I think has given planetary

644

00:30:09,810 --> 00:30:07,020

astronomers a lot to work on but I think

645

00:30:13,050 --> 00:30:09,820

it's it's been about 30 years and we're

646

00:30:17,490 --> 00:30:13,060

about you for NASA guys if you hear me

647

00:30:22,050 --> 00:30:17,500

were about you for another mission so

648

00:30:24,150 --> 00:30:22,060

this is a particular region on Europe

649

00:30:26,010 --> 00:30:24,160

and you can see the striations there

650

00:30:27,950 --> 00:30:26,020

this region is highlighted and this is

651

00:30:32,370 --> 00:30:27,960

now work that comes from a British

652

00:30:33,840 --> 00:30:32,380

Schmidt who's been working on this on

653

00:30:36,600 --> 00:30:33,850

Europa since she was I think in grad

654

00:30:39,450 --> 00:30:36,610

school and what this shows is a region

655

00:30:41,280 --> 00:30:39,460

that it looks very chaotic it looks sort

656

00:30:43,920 --> 00:30:41,290

of crumpled II like something happened

657

00:30:45,720 --> 00:30:43,930

there it's not a it's not a crater some

658

00:30:48,510 --> 00:30:45,730

typical crater has a little cone shape

659

00:30:50,340 --> 00:30:48,520

and you see the material inside but this

660

00:30:54,270 --> 00:30:50,350

seems to indicate that there might have

661

00:30:58,770 --> 00:30:54,280

been a region on the planet I mean on

662

00:31:03,720 --> 00:30:58,780

the moon that might be the source of

663

00:31:06,780 --> 00:31:03,730

some kind of flow of material a crack in

664

00:31:09,240 --> 00:31:06,790

the ice raises a material and so there

665

00:31:11,610 --> 00:31:09,250

was she developed a model that seemed to

666

00:31:15,950 --> 00:31:11,620

indicate that you had to have some kind

667

00:31:25,080 --> 00:31:15,960

of water driving this type of feature

668

00:31:29,340 --> 00:31:25,090

liquid and Galileo get to the rescue

669

00:31:32,160 --> 00:31:29,350

again and one of the John Spencer

670

00:31:34,260 --> 00:31:32,170

studied the thermal mapping of Europa

671

00:31:36,000 --> 00:31:34,270

and just because even you want to know

672

00:31:38,520 --> 00:31:36,010

what's going on what's the temperature

673

00:31:39,900 --> 00:31:38,530

on the surface is it all one the same

674

00:31:41,700 --> 00:31:39,910

temperature all around is there

675

00:31:43,320 --> 00:31:41,710

variation in the temperatures at hot

676

00:31:46,470 --> 00:31:43,330

cold is it like that the Earth's where

677

00:31:49,650 --> 00:31:46,480

the poles are colder etc and so he did

678

00:31:50,970 --> 00:31:49,660

this heat map if you will it measured

679

00:31:52,680 --> 00:31:50,980

the temperature in various locations

680

00:31:54,930 --> 00:31:52,690

this is sort of at the South Pole this

681

00:31:57,450 --> 00:31:54,940

is sort of hot you have regions where

682

00:32:01,010 --> 00:31:57,460

you go from warm relatively warm to cold

683

00:32:04,170 --> 00:32:01,020

and these are degrees um I think Kelvin

684

00:32:07,890 --> 00:32:04,180

so this also tells us that it's not as

685

00:32:12,020 --> 00:32:07,900

solidly single temperature situation

686

00:32:14,670 --> 00:32:12,030

which just adds to the to the intrigue

687

00:32:18,120 --> 00:32:14,680

so this is an a bit of an artist

688

00:32:20,550 --> 00:32:18,130

conception I think that between Galilean

689

00:32:22,710 --> 00:32:20,560

Voyager and a lot of heavy lifting by

690

00:32:23,040 --> 00:32:22,720

planetary scientists we sort of came up

691

00:32:25,050 --> 00:32:23,050

with

692

00:32:27,570 --> 00:32:25,060

the idea that we had a salty liquid

693

00:32:30,000 --> 00:32:27,580

ocean and that potentially you could

694

00:32:33,030 --> 00:32:30,010

have some kind of geyser activity if you

695

00:32:34,920 --> 00:32:33,040

had liquid water depositing here's sort

696

00:32:36,930 --> 00:32:34,930

of one of those little chaos terrains

697

00:32:38,490 --> 00:32:36,940

like the one I showed you earlier pool

698

00:32:40,620 --> 00:32:38,500

of water underneath this is probably

699

00:32:42,060 --> 00:32:40,630

some thin layer of ice about a hundred

700

00:32:43,860 --> 00:32:42,070

kilometers thick you get a little water

701
00:32:49,560 --> 00:32:43,870
pooling up and it comes up and maybe you

702
00:32:51,840 --> 00:32:49,570
could see geysers and so this seems to

703
00:32:54,870 --> 00:32:51,850
indicate all that it seems to indicate

704
00:32:58,290 --> 00:32:54,880
that this is really the right idea the

705
00:33:01,320 --> 00:32:58,300
right model for Europa so you do have a

706
00:33:03,870 --> 00:33:01,330
liquid ocean a salty liquid water ocean

707
00:33:11,330 --> 00:33:03,880
underneath ice and now things get really

708
00:33:14,820 --> 00:33:11,340
interesting because this is not Europa

709
00:33:20,580 --> 00:33:14,830
this is Enceladus which is a moon of

710
00:33:22,830 --> 00:33:20,590
Saturn and Cassini which was not did not

711
00:33:25,920 --> 00:33:22,840
go up 40 years ago more recently than

712
00:33:30,890 --> 00:33:25,930
that took a picture of Enceladus and

713
00:33:40,320 --> 00:33:30,900

noticed that there was water vapor on

714

00:33:43,730 --> 00:33:40,330

the South Pole hmm so if Cassini has

715

00:33:50,640 --> 00:33:43,740

this what about Europa

716

00:33:54,650 --> 00:33:50,650

so if Europa also has plumes of water

717

00:33:58,050 --> 00:33:54,660

vapor then maybe we can learn something

718

00:34:00,000 --> 00:33:58,060

about its ocean without necessarily

719

00:34:01,710 --> 00:34:00,010

having to go and send a mission and do

720

00:34:07,250 --> 00:34:01,720

ice cores and drill down a hundred

721

00:34:14,010 --> 00:34:12,030

so this is where Hubble comes in so and

722

00:34:19,080 --> 00:34:14,020

this is work that started roughly around

723

00:34:21,960 --> 00:34:19,090

2010 so this is Lorenz Roth it all came

724

00:34:26,210 --> 00:34:21,970

up with one technique and it's called

725

00:34:31,010 --> 00:34:28,800

which is not the same thing as direct

726

00:34:34,590 --> 00:34:31,020

imaging so we think of a spectrum as

727

00:34:36,790 --> 00:34:34,600

white light coming through a prism or a

728

00:34:38,740 --> 00:34:36,800

dispersing piece of glass and then

729

00:34:41,380 --> 00:34:38,750

getting broken up into its constituent

730

00:34:44,140 --> 00:34:41,390

colors we've all seen that or a drop of

731

00:34:47,440 --> 00:34:44,150

water or your hose or the rainbows they

732

00:34:51,070 --> 00:34:47,450

all work the same way and if you

733

00:34:52,660 --> 00:34:51,080

remember from your physics class whether

734

00:34:54,610 --> 00:34:52,670

it was high school or college or a

735

00:34:58,150 --> 00:34:54,620

graduate school or maybe even last week

736

00:35:00,280 --> 00:34:58,160

and you're analyzing some data typically

737

00:35:02,440 --> 00:35:00,290

when we do spectroscopy we talk about

738

00:35:04,210 --> 00:35:02,450

having a slit and then you have the

739

00:35:07,570 --> 00:35:04,220

dispenser in this case it's a prism and

740

00:35:09,670 --> 00:35:07,580

this is just a model it gets sent off

741

00:35:13,270 --> 00:35:09,680

collimated and what you see then is a

742

00:35:17,580 --> 00:35:13,280

bunch of lines either absorption lines

743

00:35:20,230 --> 00:35:17,590

in this case or emission lines and

744

00:35:23,230 --> 00:35:20,240

that's a normal way of doing things but

745

00:35:29,560 --> 00:35:23,240

in actuality what these little lines are

746

00:35:34,720 --> 00:35:29,570

are actually an image of the slit so

747

00:35:38,260 --> 00:35:34,730

what happens if you take a moon and you

748

00:35:40,750 --> 00:35:38,270

use your traditional small slit well you

749

00:35:43,480 --> 00:35:40,760

can't see the whole moon but if you make

750

00:35:48,100 --> 00:35:43,490

the slit bigger and fortunately Hubble

751
00:35:50,560 --> 00:35:48,110
is one of Hubble's instruments the Space

752
00:35:52,990 --> 00:35:50,570
Telescope imaging spectrograph has a

753
00:35:56,740 --> 00:35:53,000
slit that's about two arc seconds wide

754
00:36:00,700 --> 00:35:56,750
and Europa extends an angle of about one

755
00:36:03,340 --> 00:36:00,710
in a bit so you open up the slit and you

756
00:36:05,320 --> 00:36:03,350
go through your same system so this is

757
00:36:08,410 --> 00:36:05,330
now standing in for the entire set of

758
00:36:11,710 --> 00:36:08,420
optics that are complicated and what you

759
00:36:13,840 --> 00:36:11,720
get is an image that's no longer those

760
00:36:16,000 --> 00:36:13,850
straight lines but rather an image of

761
00:36:22,360 --> 00:36:16,010
the source because you've made the slit

762
00:36:24,880 --> 00:36:22,370
large enough and then the idea then is

763
00:36:27,300 --> 00:36:24,890

that we know that if there is a plume of

764

00:36:31,060 --> 00:36:27,310

water when water hits the atmosphere

765

00:36:33,220 --> 00:36:31,070

water's hydrogen h₂o two hydrogen's and

766

00:36:35,470 --> 00:36:33,230

an oxygen when it reaches the atmosphere

767

00:36:37,960 --> 00:36:35,480

will dissociate or exits the atmosphere

768

00:36:40,450 --> 00:36:37,970

it will dissociate break apart into

769

00:36:43,180 --> 00:36:40,460

hydrogen and oxygen so the logical thing

770

00:36:45,430 --> 00:36:43,190

to do would then be to look for the

771

00:36:48,280 --> 00:36:45,440

dissociation products of water which are

772

00:36:50,210 --> 00:36:48,290

hydrogen and oxygen and in the

773

00:36:53,360 --> 00:36:50,220

ultraviolet there are two

774

00:36:56,150 --> 00:36:53,370

of hydrogen and oxygen and this is what

775

00:37:00,950 --> 00:36:56,160

Lorenz Roth and his team took advantage

776

00:37:03,380 --> 00:37:00,960

of and so in 1999 this is the series of

777

00:37:06,800 --> 00:37:03,390

images this is this is the hydrogen

778

00:37:11,030 --> 00:37:06,810

lines these are the oxygen lines in 2012

779

00:37:13,640 --> 00:37:11,040

they took another series of images but

780

00:37:17,030 --> 00:37:13,650

in December of 2012 when they saw those

781

00:37:19,130 --> 00:37:17,040

images what they noticed is that unlike

782

00:37:22,670 --> 00:37:19,140

the earlier images there was a little

783

00:37:28,040 --> 00:37:22,680

excess of both hydrogen and oxygen down

784

00:37:31,060 --> 00:37:28,050

here and that indicates that there was a

785

00:37:35,270 --> 00:37:31,070

plume and they wrote a paper in science

786

00:37:38,410 --> 00:37:35,280

which is here came out in 2014 there

787

00:37:41,480 --> 00:37:38,420

were subsequent observations almost 17

788

00:37:43,700 --> 00:37:41,490

detection our orbits Lee and there were

789

00:37:47,260 --> 00:37:43,710

no additional plumes discovered so now

790

00:37:49,220 --> 00:37:47,270

that Lucknow just like with the

791

00:37:51,140 --> 00:37:49,230

presentation earlier is this the data

792

00:37:53,510 --> 00:37:51,150

did we use you know everybody thinks did

793

00:37:55,640 --> 00:37:53,520

we screw something up what's going on

794

00:37:58,220 --> 00:37:55,650

that we don't see it again get really

795

00:38:00,140 --> 00:37:58,230

panicky you think you've done something

796

00:38:02,450 --> 00:38:00,150

wrong in the analysis and you go back

797

00:38:07,880 --> 00:38:02,460

you do the reanalysis it's like no this

798

00:38:10,760 --> 00:38:07,890

was correct that really but because they

799

00:38:13,040 --> 00:38:10,770

didn't see the plumes again there was

800

00:38:14,690 --> 00:38:13,050

already hints that Europa could not be

801
00:38:20,660 --> 00:38:14,700
like Enceladus and so this is very

802
00:38:23,060 --> 00:38:20,670
regular cryovolcanism if you will so if

803
00:38:25,220 --> 00:38:23,070
you wanted to get a pretty picture and

804
00:38:30,460 --> 00:38:25,230
put it together so this is the location

805
00:38:34,370 --> 00:38:30,470
of the plumes and then here is um Europa

806
00:38:35,960 --> 00:38:34,380
okay the other thing about science is

807
00:38:39,530 --> 00:38:35,970
that you like people to repeat your

808
00:38:41,540 --> 00:38:39,540
experiment in some other way so that you

809
00:38:44,300 --> 00:38:41,550
have some confidence of what you're

810
00:38:47,060 --> 00:38:44,310
doing so the second method was to

811
00:38:48,620 --> 00:38:47,070
actually use direct imaging so no longer

812
00:38:49,880 --> 00:38:48,630
using spectrograph but just direct

813
00:38:51,860 --> 00:38:49,890

imaging just like you do with your

814

00:38:53,380 --> 00:38:51,870

camera and take a picture of somebody or

815

00:38:56,740 --> 00:38:53,390

the tree or the Pussycats

816

00:39:01,280 --> 00:38:56,750

okay that's direct imaging in this case

817

00:39:02,870 --> 00:39:01,290

there have been an example in 2000 John

818

00:39:05,120 --> 00:39:02,880

Spencer had looked at he

819

00:39:07,010 --> 00:39:05,130

in the ultraviolet so this is e oh and

820

00:39:08,180 --> 00:39:07,020

this is Jupiter in the background you

821

00:39:11,960 --> 00:39:08,190

can see there's a little plume here

822

00:39:15,910 --> 00:39:11,970

remember yo really is volcanic and so

823

00:39:19,240 --> 00:39:15,920

the idea was that look if this worked

824

00:39:23,890 --> 00:39:19,250

for IO where you can have Jupiter

825

00:39:26,150 --> 00:39:23,900

effectively back light so you're seeing

826

00:39:28,190 --> 00:39:26,160

Jupiter in the back back lighting the

827

00:39:29,960 --> 00:39:28,200

atmosphere of the of the of the of the

828

00:39:31,640 --> 00:39:29,970

moon the tenuous atmosphere if there's

829

00:39:37,160 --> 00:39:31,650

anything going on you should be able to

830

00:39:39,170 --> 00:39:37,170

detect it so the second idea then was to

831

00:39:42,140 --> 00:39:39,180

do direct imaging in the farl travaille

832

00:39:44,000 --> 00:39:42,150

ilat around 150 hundred and 60

833

00:39:47,590 --> 00:39:44,010

nanometers this is a region that is of

834

00:39:51,710 --> 00:39:47,600

course not accessible from the ground

835

00:39:55,220 --> 00:39:51,720

and we took images for almost three

836

00:39:57,920 --> 00:39:55,230

years well two years and we had 12

837

00:39:59,240 --> 00:39:57,930

images of Europa in transit and what we

838

00:40:02,800 --> 00:39:59,250

were doing then was measuring the

839

00:40:05,810 --> 00:40:02,810

atmosphere not necessarily looking for

840

00:40:07,970 --> 00:40:05,820

Jets but just changes in the in the in

841

00:40:09,950 --> 00:40:07,980

the thickness or the opacity of the

842

00:40:11,630 --> 00:40:09,960

atmosphere and we also just to

843

00:40:13,310 --> 00:40:11,640

double-check had images taken out of

844

00:40:18,200 --> 00:40:13,320

transit just in case I had something to

845

00:40:21,350 --> 00:40:18,210

do is being in front of Jupiter and the

846

00:40:23,090 --> 00:40:21,360

analysis of this data was is pretty

847

00:40:24,950 --> 00:40:23,100

straightforward here's the real image of

848

00:40:27,050 --> 00:40:24,960

Europa and this is Jupiter in the

849

00:40:28,400 --> 00:40:27,060

background and what you want to make

850

00:40:30,620 --> 00:40:28,410

sure is that that when you do the

851

00:40:32,090 --> 00:40:30,630

subtraction in R the analysis of the

852

00:40:32,780 --> 00:40:32,100

image that you're not doing anything

853

00:40:35,090 --> 00:40:32,790

crazy

854

00:40:38,030 --> 00:40:35,100

so the standard thing to do is to say

855

00:40:43,990 --> 00:40:38,040

assume a circle with a and you assume

856

00:40:46,550 --> 00:40:44,000

some kind of illumination pattern you

857

00:40:48,560 --> 00:40:46,560

figure out what Jupiter looks like in

858

00:40:52,160 --> 00:40:48,570

the background you make a model and then

859

00:40:53,870 --> 00:40:52,170

you subtract the model you actually also

860

00:40:55,250 --> 00:40:53,880

have to add you know the effects of the

861

00:40:57,680 --> 00:40:55,260

instrument on your model so you

862

00:40:59,210 --> 00:40:57,690

basically you're making a fake image so

863

00:41:03,460 --> 00:40:59,220

here's the fake image and here's the

864

00:41:05,780 --> 00:41:03,470

real image and they look okay they look

865

00:41:08,270 --> 00:41:05,790

plausible this is one that doesn't have

866

00:41:09,470 --> 00:41:08,280

plumes and this one in the model doesn't

867

00:41:11,750 --> 00:41:09,480

have it either so this tells you

868

00:41:14,060 --> 00:41:11,760

something about the gives you some

869

00:41:16,130 --> 00:41:14,070

confidence that your method is actually

870

00:41:18,590 --> 00:41:16,140

going to work

871

00:41:21,410 --> 00:41:18,600

and then just for fun you're just what

872

00:41:24,020 --> 00:41:21,420

these images look like here because

873

00:41:25,400 --> 00:41:24,030

Jupiter moves now here's the fun part of

874

00:41:27,200 --> 00:41:25,410

doing planetary science which I hadn't

875

00:41:29,290 --> 00:41:27,210

quite appreciated until I started doing

876

00:41:32,630 --> 00:41:29,300

it myself is that everything moves

877

00:41:34,780 --> 00:41:32,640

Jupiter moves Europa moves the satellite

878

00:41:36,800 --> 00:41:34,790

moves so everything has to somehow work

879

00:41:38,150 --> 00:41:36,810

together and you have to decide whether

880

00:41:41,270 --> 00:41:38,160

you're going to track on the moon or

881

00:41:44,570 --> 00:41:41,280

Jupiter or both so this is what it looks

882

00:41:47,270 --> 00:41:44,580

like if you assume that Jupiter isn't

883

00:41:49,390 --> 00:41:47,280

moving and then here if you assume

884

00:41:51,860 --> 00:41:49,400

Europa isn't moving so here's Europa and

885

00:41:56,930 --> 00:41:51,870

here's a shadow and that there's a no

886

00:41:59,930 --> 00:41:56,940

lovely Aurora and then I have to UM show

887

00:42:02,960 --> 00:41:59,940

this because this is kind of fun if you

888

00:42:04,490 --> 00:42:02,970

put all the images together and you D

889

00:42:08,270 --> 00:42:04,500

rotate everything then you could make

890

00:42:10,700 --> 00:42:08,280

fun images that show you here's Europa

891

00:42:12,050 --> 00:42:10,710

yours yo here's the Great Red Spot and

892

00:42:15,410 --> 00:42:12,060

obviously it's a partial them is because

893

00:42:20,000 --> 00:42:15,420

we're not imaging the whole of Jupiter's

894

00:42:21,680 --> 00:42:20,010

face so that's kind of fun and the

895

00:42:25,070 --> 00:42:21,690

reason we could do this is that one of

896

00:42:28,580 --> 00:42:25,080

the advantage of this disc spectrograph

897

00:42:31,700 --> 00:42:28,590

or imaging system is that you can

898

00:42:33,800 --> 00:42:31,710

actually take observations at what's

899

00:42:37,070 --> 00:42:33,810

called time tags so that the separation

900

00:42:39,560 --> 00:42:37,080

each each exposure is 0.125 seconds and

901
00:42:41,420 --> 00:42:39,570
you just can keep doing that so every

902
00:42:43,220 --> 00:42:41,430
tenth of a second you have a new image

903
00:42:45,710 --> 00:42:43,230
which is one of the things that lets you

904
00:42:47,450 --> 00:42:45,720
make these lovely movies but it also

905
00:42:52,160 --> 00:42:47,460
helps if you're trying to look for

906
00:42:54,620 --> 00:42:52,170
features and then you can also play some

907
00:42:57,680 --> 00:42:54,630
more with these images and this was made

908
00:43:01,010 --> 00:42:57,690
by Sean Lockwood who's also on the staff

909
00:43:03,050 --> 00:43:01,020
here and from the same data because the

910
00:43:04,190 --> 00:43:03,060
movies are kind of fun what's the point

911
00:43:06,110 --> 00:43:04,200
of doing this if you can't have fun so

912
00:43:09,130 --> 00:43:06,120
here you see the aurora which is kind of

913
00:43:12,380 --> 00:43:09,140

fun it changes with time and here is

914

00:43:15,200 --> 00:43:12,390

Europa so this is you know not not

915

00:43:17,900 --> 00:43:15,210

enhanced at all and then if you really

916

00:43:19,790 --> 00:43:17,910

want to see but again unenhanced so

917

00:43:21,920 --> 00:43:19,800

we'll just skip right right past this

918

00:43:24,200 --> 00:43:21,930

because the thing that's interesting is

919

00:43:26,030 --> 00:43:24,210

that what we're looking for is 3,000

920

00:43:28,580 --> 00:43:26,040

kilometers and this is Europa's north

921

00:43:30,490 --> 00:43:28,590

and then just to show you because you

922

00:43:32,930 --> 00:43:30,500

got to show the data

923

00:43:34,400 --> 00:43:32,940

I've talked a lot about it I've shown

924

00:43:38,110 --> 00:43:34,410

some pretty movies but I haven't shown

925

00:43:45,680 --> 00:43:38,120

you the data but you should always ask

926
00:43:48,350 --> 00:43:45,690
so these are the twelve ten of the

927
00:43:51,200 --> 00:43:48,360
twelve observations that we took and one

928
00:43:53,120 --> 00:43:51,210
two three four five actually one two and

929
00:43:55,670 --> 00:43:53,130
they're given in time so we started in

930
00:43:59,930 --> 00:43:55,680
twin December of 2013 through March of

931
00:44:01,820 --> 00:43:59,940
2015 and we did that whole careful

932
00:44:04,940 --> 00:44:01,830
analysis subtracting out the model

933
00:44:08,150 --> 00:44:04,950
making sure and you'll notice if you

934
00:44:10,490 --> 00:44:08,160
look carefully that there are only three

935
00:44:12,410 --> 00:44:10,500
of these images that should look that

936
00:44:18,200 --> 00:44:12,420
show something different three of these

937
00:44:26,300 --> 00:44:18,210
are not like the others and those are

938
00:44:28,310 --> 00:44:26,310

the plumes maybe okay and this is just a

939

00:44:30,080 --> 00:44:28,320

close-up and what these are done here is

940

00:44:34,370 --> 00:44:30,090

you subtract the model out and again you

941

00:44:35,870 --> 00:44:34,380

see the enhancement so I know that we

942

00:44:37,490 --> 00:44:35,880

had a lot of discussion because now we

943

00:44:39,860 --> 00:44:37,500

saw three-d-- we didn't see them

944

00:44:41,960 --> 00:44:39,870

sequentially and then we looked at the

945

00:44:44,930 --> 00:44:41,970

roth paper and it looked like they were

946

00:44:46,880 --> 00:44:44,940

in the same location and in addition we

947

00:44:48,860 --> 00:44:46,890

actually found a plume in a different

948

00:44:52,970 --> 00:44:48,870

location the other ones were down here

949

00:44:55,900 --> 00:44:52,980

in March of 2017 we actually found

950

00:44:59,150 --> 00:44:55,910

something a little Pucci thing over here

951
00:45:02,450 --> 00:44:59,160
that repeated again there so that that

952
00:45:09,050 --> 00:45:02,460
would be a second second plume that's

953
00:45:10,700 --> 00:45:09,060
really cool this is just more of the

954
00:45:12,170 --> 00:45:10,710
images and then just to prove that we

955
00:45:15,590 --> 00:45:12,180
weren't kidding ourselves we added

956
00:45:17,270 --> 00:45:15,600
subtracted and convinced ourselves that

957
00:45:24,170 --> 00:45:17,280
that was right so where are these plumes

958
00:45:26,810 --> 00:45:24,180
found so the ones that the eight the the

959
00:45:29,630 --> 00:45:26,820
direct method the direct imaging method

960
00:45:31,430 --> 00:45:29,640
found right just north of the South Pole

961
00:45:35,110 --> 00:45:31,440
and then right here near this crater

962
00:45:38,990 --> 00:45:35,120
called quill and we saw it twice

963
00:45:40,820 --> 00:45:39,000

so the plume at will be repeated we saw

964

00:45:42,980 --> 00:45:40,830

that twice this one we've only seen once

965

00:45:45,230 --> 00:45:42,990

and this is the location

966

00:45:49,190 --> 00:45:45,240

of the plume as seen it with the

967

00:45:49,970 --> 00:45:49,200

spectroscopic method so we have one two

968

00:45:53,960 --> 00:45:49,980

three

969

00:45:55,190 --> 00:45:53,970

plumes if you count them and one of the

970

00:45:56,990 --> 00:45:55,200

things that's really need you've seen

971

00:46:03,260 --> 00:45:57,000

this image before cuz I showed it to you

972

00:46:05,720 --> 00:46:03,270

earlier is that here's well this region

973

00:46:07,700 --> 00:46:05,730

here is like two degrees warmer than the

974

00:46:11,600 --> 00:46:07,710

surrounding region and that's coincident

975

00:46:14,450 --> 00:46:11,610

with what with that repeating plume so

976

00:46:17,030 --> 00:46:14,460

the question we're asking is are they

977

00:46:19,220 --> 00:46:17,040

related is it possible that you could

978

00:46:21,830 --> 00:46:19,230

have a slight warming of the ice would

979

00:46:24,140 --> 00:46:21,840

that be enough to allow some liquid

980

00:46:26,600 --> 00:46:24,150

water to come through to sort of break

981

00:46:32,450 --> 00:46:26,610

through that's a it's intriguing we we

982

00:46:35,450 --> 00:46:32,460

don't know but it's a possibility and so

983

00:46:38,570 --> 00:46:35,460

this might be what that looks like that

984

00:46:40,280 --> 00:46:38,580

plume 100 rising 125 miles above the

985

00:46:45,260 --> 00:46:40,290

surface and of course there's a Jupiter

986

00:46:53,270 --> 00:46:45,270

in the background so um looks like there

987

00:46:54,920 --> 00:46:53,280

it's probably water on on Europa and the

988

00:47:00,260 --> 00:46:54,930

observations continue we didn't just

989

00:47:02,000 --> 00:47:00,270

stop in 2017 both groups have has

990

00:47:03,740 --> 00:47:02,010

amorphous as they are have are

991

00:47:04,640 --> 00:47:03,750

continuing their observations using

992

00:47:08,390 --> 00:47:04,650

different techniques and different

993

00:47:12,170 --> 00:47:08,400

analysis methods so this is um from our

994

00:47:15,349 --> 00:47:12,180

most recent 2017-2018 data taken with

995

00:47:18,140 --> 00:47:15,359

the Hubble Space Telescope and again

996

00:47:20,690 --> 00:47:18,150

it's really kind of fun to see them and

997

00:47:23,750 --> 00:47:20,700

move around this is Ganymede up here by

998

00:47:26,120 --> 00:47:23,760

the way that isn't just a splash you can

999

00:47:29,540 --> 00:47:26,130

see you rope over there and you can see

1000

00:47:35,840 --> 00:47:29,550

that lovely I love the Aurora on the on

1001
00:47:40,070 --> 00:47:35,850
the poles of Jupiter okay so that's fun

1002
00:47:44,390 --> 00:47:40,080
there's a close-up of Ganymede so if you

1003
00:47:47,510 --> 00:47:44,400
have water we have ice we think we have

1004
00:47:50,150 --> 00:47:47,520
water the good thing is that both groups

1005
00:47:54,580 --> 00:47:50,160
got the same value when you do all your

1006
00:47:58,130 --> 00:47:56,630
coincident so that the sparks

1007
00:48:01,099 --> 00:47:58,140
diamond arrived found one plume

1008
00:48:04,370 --> 00:48:01,109
coincident or near each other and we saw

1009
00:48:08,930 --> 00:48:04,380
one that repeated but we also determined

1010
00:48:10,700 --> 00:48:08,940
the amount of water based on the on the

1011
00:48:12,079 --> 00:48:10,710
images that the amount of water was

1012
00:48:14,029 --> 00:48:12,089
about the same so you don't get the same

1013
00:48:16,670 --> 00:48:14,039

numbers unless you're more or less on

1014

00:48:20,000 --> 00:48:16,680

the right track so now we have the

1015

00:48:21,710 --> 00:48:20,010

ingredients for life so we have so what

1016

00:48:23,450 --> 00:48:21,720

do you need you need atoms you need

1017

00:48:27,400 --> 00:48:23,460

molecules you need the most important

1018

00:48:33,049 --> 00:48:27,410

molecule of all h₂o and you need energy

1019

00:48:38,230 --> 00:48:33,059

now a nurse the energy that life as we

1020

00:48:41,980 --> 00:48:38,240

know it uses tens it comes from the Sun

1021

00:48:46,670 --> 00:48:41,990

plants the animals that eat the plants

1022

00:48:50,269 --> 00:48:46,680

algae slime mold bedbugs etc I'll derive

1023

00:48:53,829 --> 00:48:50,279

the energy required to synthesize these

1024

00:48:56,319 --> 00:48:53,839

elements into the amino acids along

1025

00:48:58,970 --> 00:48:56,329

biochemistry chain that happens

1026

00:49:01,039 --> 00:48:58,980

sometimes on earth we have hydrothermal

1027

00:49:03,680 --> 00:49:01,049

vents go to the bottom of the ocean

1028

00:49:06,259 --> 00:49:03,690

there are there's well volcanic activity

1029

00:49:08,029 --> 00:49:06,269

and that heats up the water and you get

1030

00:49:11,029 --> 00:49:08,039

these hydrothermal vents and we found

1031

00:49:14,779 --> 00:49:11,039

what we yeah and people have looked and

1032

00:49:19,670 --> 00:49:14,789

found at life bacteria and so forth

1033

00:49:21,829 --> 00:49:19,680

living there and this is a model sort of

1034

00:49:24,319 --> 00:49:21,839

indicating the tidal heating so if you

1035

00:49:27,079 --> 00:49:24,329

don't have direct energy from the Sun

1036

00:49:29,660 --> 00:49:27,089

and you may or may not have hydrothermal

1037

00:49:32,529 --> 00:49:29,670

vents you still need a source of energy

1038

00:49:37,279 --> 00:49:32,539

in order to be able to do the chemistry

1039

00:49:40,190 --> 00:49:37,289

that allows bio the biology to happen

1040

00:49:42,559 --> 00:49:40,200

and in Europa this is this would be due

1041

00:49:51,410 --> 00:49:42,569

to the tidal heating so there is an

1042

00:49:54,490 --> 00:49:51,420

energy source and many years of people

1043

00:49:59,210 --> 00:49:54,500

studying evolution so life on Earth is

1044

00:50:02,390 --> 00:49:59,220

divided into three clouds okay three

1045

00:50:05,420 --> 00:50:02,400

different groups we have what's what are

1046

00:50:06,800 --> 00:50:05,430

called the bacteria some of them we

1047

00:50:09,210 --> 00:50:06,810

don't like

1048

00:50:10,680 --> 00:50:09,220

these are single-celled generally

1049

00:50:12,620 --> 00:50:10,690

single-cell animals we have what's

1050

00:50:16,050 --> 00:50:12,630

called the archaea and those are

1051

00:50:20,040 --> 00:50:16,060

generally those those extremophiles

1052

00:50:22,530 --> 00:50:20,050

those organisms that like to live or

1053

00:50:24,870 --> 00:50:22,540

it's super salty super acidic super

1054

00:50:28,980 --> 00:50:24,880

alkaline super hot super cold super high

1055

00:50:32,070 --> 00:50:28,990

pressure super low pressure and then we

1056

00:50:32,700 --> 00:50:32,080

have the Eukarya and that's everything

1057

00:50:36,300 --> 00:50:32,710

else

1058

00:50:42,750 --> 00:50:36,310

this is slime molds bedbugs people cats

1059

00:50:44,790 --> 00:50:42,760

dogs your neighbor and I just put down

1060

00:50:46,890 --> 00:50:44,800

this last common ancestor because it's

1061

00:50:49,260 --> 00:50:46,900

kind of cool to see the quote unquote

1062

00:50:51,270 --> 00:50:49,270

Tree of Life if this one gets very messy

1063

00:50:56,060 --> 00:50:51,280

and so does this one so I just put

1064

00:50:59,850 --> 00:50:56,070

clouds but the main difference between

1065

00:51:03,450 --> 00:50:59,860

the left side and the right side is the

1066

00:51:05,880 --> 00:51:03,460

kind of cell that makes up the different

1067

00:51:08,010 --> 00:51:05,890

kinds of life and I have a question mark

1068

00:51:13,110 --> 00:51:08,020

for the viruses because I don't nobody

1069

00:51:15,600 --> 00:51:13,120

really knows where they fit in so these

1070

00:51:19,980 --> 00:51:15,610

guys have one particular kind of cell is

1071

00:51:22,830 --> 00:51:19,990

very simple and these organisms over

1072

00:51:28,910 --> 00:51:22,840

here do are all single-cell organisms

1073

00:51:31,770 --> 00:51:28,920

whereas as we know on this side whoa on

1074

00:51:33,570 --> 00:51:31,780

this side we have multicellular

1075

00:51:35,940 --> 00:51:33,580

organisms as well as single cellular

1076

00:51:38,880 --> 00:51:35,950

organisms and the cells are more

1077

00:51:40,200 --> 00:51:38,890

complicated how you know things like

1078

00:51:41,670 --> 00:51:40,210

that then you start getting into things

1079

00:51:45,300 --> 00:51:41,680

like how is the information for

1080

00:51:47,430 --> 00:51:45,310

replication or reproduction carried in

1081

00:51:50,220 --> 00:51:47,440

in the cells of different structures

1082

00:51:57,000 --> 00:51:50,230

that do that I think on this side the

1083

00:51:59,070 --> 00:51:57,010

eukaryotes over here on the right as you

1084

00:52:01,260 --> 00:51:59,080

can see these are real electronic

1085

00:52:04,200 --> 00:52:01,270

scanning electron images of these

1086

00:52:07,140 --> 00:52:04,210

critters so this cell has here's the

1087

00:52:08,730 --> 00:52:07,150

nucleus this is where the DNA lives all

1088

00:52:09,870 --> 00:52:08,740

the genetic information and you see they

1089

00:52:11,210 --> 00:52:09,880

have all these structures of

1090

00:52:13,920 --> 00:52:11,220

mitochondria furtive doing like

1091

00:52:16,710 --> 00:52:13,930

mitochondrial DNA analyses to see where

1092

00:52:18,710 --> 00:52:16,720

people came from that's what they're

1093

00:52:20,200 --> 00:52:18,720

looking for is the DNA that's in the

1094

00:52:21,550 --> 00:52:20,210

mitochondria you have the

1095

00:52:24,190 --> 00:52:21,560

plasma you have a whole bunch of

1096

00:52:29,310 --> 00:52:24,200

structures and this is where all the

1097

00:52:31,870 --> 00:52:29,320

biochemistry happens that that is life

1098

00:52:34,390 --> 00:52:31,880

whereas on this side these are the probe

1099

00:52:36,400 --> 00:52:34,400

the prokaryotes whether they're bacteria

1100

00:52:38,380 --> 00:52:36,410

or archaea they're really simple

1101
00:52:39,970 --> 00:52:38,390
they here's something that's called the

1102
00:52:43,510 --> 00:52:39,980
nucleoid

1103
00:52:45,190 --> 00:52:43,520
and all the DNA is is there and then you

1104
00:52:47,230 --> 00:52:45,200
can see there's just a couple of

1105
00:52:55,599 --> 00:52:47,240
structures in there so they're very

1106
00:52:57,820 --> 00:52:55,609
simple and of course on as we know from

1107
00:53:00,220 --> 00:52:57,830
you know everything that's the Eukarya

1108
00:53:03,730 --> 00:53:00,230
we have planned so they have solid cells

1109
00:53:05,980 --> 00:53:03,740
so the cells on this side ER are very

1110
00:53:10,540 --> 00:53:05,990
can be differentiated and have specific

1111
00:53:13,510 --> 00:53:10,550
purposes so here we go so life on Earth

1112
00:53:14,260 --> 00:53:13,520
the bacteria this is actually a picture

1113
00:53:19,930 --> 00:53:14,270

of e---coli

1114

00:53:21,940 --> 00:53:19,940

I had to find one that was a key this is

1115

00:53:25,000 --> 00:53:21,950

a meth an o-5

1116

00:53:28,230 --> 00:53:25,010

philic animal it loves methane and lives

1117

00:53:30,730 --> 00:53:28,240

where there's a lot of methane this is a

1118

00:53:33,250 --> 00:53:30,740

single-cell organisms rather than algae

1119

00:53:34,810 --> 00:53:33,260

and then here's the great white whale so

1120

00:53:36,339 --> 00:53:34,820

this side we have a lot of diversity

1121

00:53:39,670 --> 00:53:36,349

here we have a lot of diversity but

1122

00:53:41,170 --> 00:53:39,680

they're unicellular so then let's ask

1123

00:53:47,440 --> 00:53:41,180

the question of what would life on

1124

00:53:51,160 --> 00:53:47,450

Europa look like and it is probably not

1125

00:53:54,339 --> 00:53:51,170

going to be what we think of life it is

1126
00:53:56,050 --> 00:53:54,349
probably going to be something called

1127
00:53:58,599 --> 00:53:56,060
extremophiles now there are some

1128
00:54:02,859 --> 00:53:58,609
bacteria that are extremophiles and some

1129
00:54:05,230 --> 00:54:02,869
of these guys are extremophiles so these

1130
00:54:09,099 --> 00:54:05,240
are sort of the temperature ranges - 18

1131
00:54:11,650 --> 00:54:09,109
to 15 degrees Celsius 60 121 degrees

1132
00:54:17,470 --> 00:54:11,660
remember water at sea level boils at a

1133
00:54:22,270 --> 00:54:17,480
hundred degrees Celsius pressure is like

1134
00:54:24,940 --> 00:54:22,280
from 1/100 of an atmosphere to 1,300

1135
00:54:26,589 --> 00:54:24,950
times our nurse atmosphere so obviously

1136
00:54:29,680 --> 00:54:26,599
this would be at the bottom of the ocean

1137
00:54:32,380 --> 00:54:29,690
in the deep trenches this might be sort

1138
00:54:33,850 --> 00:54:32,390

of on the top of a mountain they can

1139

00:54:38,410 --> 00:54:33,860

live in places that are up to

1140

00:54:42,540 --> 00:54:38,420

38% salt and just as an example seawater

1141

00:54:46,080 --> 00:54:42,550

is only three percent salt whoops

1142

00:54:51,610 --> 00:54:46,090

some of them like to be really acid

1143

00:54:54,280 --> 00:54:51,620

sulfuric acid is about two and then we

1144

00:54:57,340 --> 00:54:54,290

have very basic eight to twelve most of

1145

00:54:59,320 --> 00:54:57,350

us love like seven and then some of them

1146

00:55:00,100 --> 00:54:59,330

can also withstand a lot of ionizing

1147

00:55:02,410 --> 00:55:00,110

radiation

1148

00:55:05,350 --> 00:55:02,420

so that would be x-rays gamma rays

1149

00:55:07,630 --> 00:55:05,360

ultraviolet even some of the products

1150

00:55:10,030 --> 00:55:07,640

from radioactive decay and they also

1151
00:55:11,680 --> 00:55:10,040
seem to be very resistant there are some

1152
00:55:13,630 --> 00:55:11,690
that are very resistant to cosmic rays

1153
00:55:15,610 --> 00:55:13,640
and you have to remember that for

1154
00:55:19,270 --> 00:55:15,620
example when people are talking about

1155
00:55:22,480 --> 00:55:19,280
traveling from Earth to Mars or to any

1156
00:55:25,750 --> 00:55:22,490
of the other planets humans one of the

1157
00:55:29,050 --> 00:55:25,760
things that people worry about in

1158
00:55:30,610 --> 00:55:29,060
transporting humans across space is the

1159
00:55:34,060 --> 00:55:30,620
effect of cosmic rays these are very

1160
00:55:37,630 --> 00:55:34,070
high-energy charged particles and they

1161
00:55:39,520 --> 00:55:37,640
damage cells and can lead to things like

1162
00:55:42,400 --> 00:55:39,530
like cancer and disease so that is

1163
00:55:46,350 --> 00:55:42,410

always a concern on say interplanetary

1164

00:55:48,880 --> 00:55:46,360

travel for humans is how to protect

1165

00:55:50,020 --> 00:55:48,890

living creatures from cosmic rays but it

1166

00:55:53,770 --> 00:55:50,030

turns out there are some of these

1167

00:56:01,150 --> 00:55:53,780

extremophiles that are happy to deal

1168

00:56:03,550 --> 00:56:01,160

with it so here I have two images here's

1169

00:56:07,900 --> 00:56:03,560

another bacterium this is actually a

1170

00:56:13,360 --> 00:56:07,910

hallow salt-loving bacterium and this is

1171

00:56:15,690 --> 00:56:13,370

a giant squid and Europa probably

1172

00:56:19,840 --> 00:56:15,700

doesn't have the giant squid so I think

1173

00:56:23,260 --> 00:56:19,850

we're going to see the bacteria and the

1174

00:56:28,090 --> 00:56:23,270

Archaea living in Europa and where would

1175

00:56:32,230 --> 00:56:28,100

they be found well here's a scale so

1176
00:56:34,570 --> 00:56:32,240
here's only some somebodies view the

1177
00:56:38,110 --> 00:56:34,580
view is that there is probably a

1178
00:56:45,100 --> 00:56:38,120
hypothermic vent or hyper thermal vents

1179
00:56:46,680 --> 00:56:45,110
in the deep ocean of Europa that heats

1180
00:56:50,130 --> 00:56:46,690
up the water

1181
00:56:53,700 --> 00:56:50,140
and then you sets up a convection which

1182
00:56:56,760 --> 00:56:53,710
allows the I want to call it the

1183
00:56:59,760 --> 00:56:56,770
nutritive 's but the basic elements that

1184
00:57:05,870 --> 00:56:59,770
are used by for biochemistry as we know

1185
00:57:11,370 --> 00:57:05,880
it carbon oxygen phosphorus etc and then

1186
00:57:14,190 --> 00:57:11,380
life bacteria archaea would end up

1187
00:57:18,630 --> 00:57:14,200
living at the bottom and sheets perhaps

1188
00:57:21,960 --> 00:57:18,640

or upside down mounds on the bottom of

1189

00:57:25,050 --> 00:57:21,970

the ice some of them might actually if

1190

00:57:26,910 --> 00:57:25,060

there were soft ice or a vent some of

1191

00:57:29,370 --> 00:57:26,920

these um living creatures might actually

1192

00:57:32,010 --> 00:57:29,380

end up working their way up to the

1193

00:57:34,770 --> 00:57:32,020

surface much the same way that rocks and

1194

00:57:36,540 --> 00:57:34,780

meteorites in the South Pole worked

1195

00:57:38,849 --> 00:57:36,550

their way up to the surface they just

1196

00:57:40,559 --> 00:57:38,859

get dredged up or I forget what the

1197

00:57:44,220 --> 00:57:40,569

actual word is for it

1198

00:57:47,579 --> 00:57:44,230

well dredged up by the physical forces

1199

00:57:49,589 --> 00:57:47,589

and from the surface of Europa you can

1200

00:57:53,040 --> 00:57:49,599

get some of the oxides

1201

00:57:55,470 --> 00:57:53,050

I think alum molecules with oxygen in

1202

00:57:57,870 --> 00:57:55,480

them might also make their way down sort

1203

00:58:00,750 --> 00:57:57,880

of in the same way through fissures in

1204

00:58:03,089 --> 00:58:00,760

the in the ice and so it is highly

1205

00:58:07,980 --> 00:58:03,099

likely that you would end up with life

1206

00:58:12,990 --> 00:58:07,990

on Europa living on the ice shelves and

1207

00:58:16,770 --> 00:58:13,000

so the next question is what comes next

1208

00:58:18,809 --> 00:58:16,780

and there are NASA has been looking at a

1209

00:58:22,280 --> 00:58:18,819

concept called the Europa clipper which

1210

00:58:25,380 --> 00:58:22,290

is a mission to go to Europa and

1211

00:58:28,050 --> 00:58:25,390

possibly fly through a plume and see if

1212

00:58:30,059 --> 00:58:28,060

any of these if there was any what's

1213

00:58:32,010 --> 00:58:30,069

what's in the plumes could there be some

1214

00:58:34,710 --> 00:58:32,020

biological material in the plumes

1215

00:58:37,230 --> 00:58:34,720

desiccated of course but would they be

1216

00:58:39,660 --> 00:58:37,240

there would it be possible to send some

1217

00:58:41,970 --> 00:58:39,670

type of a probe that would land on the

1218

00:58:45,809 --> 00:58:41,980

surface of Europa and perhaps be able to

1219

00:58:48,450 --> 00:58:45,819

either cozy up to one of those little

1220

00:58:51,540 --> 00:58:48,460

chaotic pieces of terrain or a soft spot

1221

00:58:56,940 --> 00:58:51,550

or near one of these plumes and actually

1222

00:58:58,740 --> 00:58:56,950

do some contact excavation and I I think

1223

00:59:00,330 --> 00:58:58,750

that would be really really cool so but

1224

00:59:02,550 --> 00:59:00,340

this is something that is being stai

1225

00:59:08,460 --> 00:59:02,560

very actively because this would be

1226
00:59:10,710 --> 00:59:08,470
perhaps Europa is after Earth's we were

1227
00:59:15,540 --> 00:59:10,720
we know there's life would is the next

1228
00:59:18,630 --> 00:59:15,550
most likely location suitable for liquid

1229
00:59:21,390 --> 00:59:18,640
carbon life as we know it in the solar

1230
00:59:24,030 --> 00:59:21,400
system and that would be super exciting

1231
00:59:25,740 --> 00:59:24,040
I think if something went there and we

1232
00:59:28,440 --> 00:59:25,750
discovered there was life there I think

1233
00:59:30,900 --> 00:59:28,450
it would also be super interesting if we

1234
00:59:32,820 --> 00:59:30,910
didn't find life there because then you

1235
00:59:34,890 --> 00:59:32,830
could ask the question was there ever

1236
00:59:37,890 --> 00:59:34,900
life how would you know would you be

1237
00:59:40,680 --> 00:59:37,900
able to find fossils on earth we do find

1238
00:59:44,100 --> 00:59:40,690

the people who look for them have found

1239

00:59:47,730 --> 00:59:44,110

fossilized bacteria so it's possible one

1240

00:59:50,520 --> 00:59:47,740

could find telltale signs of past life

1241

00:59:55,650 --> 00:59:50,530

or perhaps life hasn't actually started

1242

00:59:58,370 --> 00:59:55,660

yet these are all possibilities so I'm

1243

01:00:03,210 --> 00:59:58,380

just going to and here with one last

1244

01:00:06,390 --> 01:00:03,220

slide I don't know if it was Galileo's

1245

01:00:08,790 --> 01:00:06,400

dream to go to Europa or not in 400

1246

01:00:12,320 --> 01:00:08,800

years ago but I think he would certainly

1247

01:00:17,490 --> 01:00:12,330

be interested and would probably be a

1248

01:00:20,690 --> 01:00:17,500

promoter of exploring the icy moons this

1249

01:00:27,770 --> 01:00:20,700

also turns out to be a pretty good book

1250

01:00:42,080 --> 01:00:39,940

[Applause]

1251
01:00:43,900 --> 01:00:42,090
guess we have time for questions

1252
01:00:45,980 --> 01:00:43,910
oh we had plenty of time for questions

1253
01:00:48,490 --> 01:00:45,990
including a few that up here that

1254
01:00:50,500 --> 01:00:48,500
they're gonna come from online as well

1255
01:01:02,660 --> 01:00:50,510
[Laughter]

1256
01:01:04,580 --> 01:01:02,670
yes okay so I have to repeat the

1257
01:01:06,320 --> 01:01:04,590
question for the online audience can the

1258
01:01:07,550 --> 01:01:06,330
hub will be turned back on earth to look

1259
01:01:11,900 --> 01:01:07,560
for the same sort of things we might be

1260
01:01:15,620 --> 01:01:11,910
looking for on Europa the short answers

1261
01:01:21,650 --> 01:01:15,630
no Hubble is actually designed to avoid

1262
01:01:24,670 --> 01:01:21,660
looking down on Earth for logical

1263
01:01:28,000 --> 01:01:24,680

reasons but there are other satellites

1264

01:01:30,890 --> 01:01:28,010

whose missions are to look down on earth

1265

01:01:33,470 --> 01:01:30,900

so there are as a whole suite of Earth

1266

01:01:38,110 --> 01:01:33,480

observing satellites now I don't know

1267

01:01:48,350 --> 01:01:44,120

all of the sensing equipment to be able

1268

01:01:49,970 --> 01:01:48,360

to look for life but I did that is not

1269

01:01:51,890 --> 01:01:49,980

that is one of the few things Hubble

1270

01:02:13,280 --> 01:01:51,900

cannot do is turn turn around and look

1271

01:02:16,370 --> 01:02:13,290

at and look at hers we're here that's

1272

01:02:19,040 --> 01:02:16,380

actually some okay so the question is

1273

01:02:23,360 --> 01:02:19,050

does that is does the effect of the

1274

01:02:26,960 --> 01:02:23,370

tidal forcing of the or the tidal

1275

01:02:29,990 --> 01:02:26,970

heating of Europa coincide with where

1276

01:02:32,210 --> 01:02:30,000

you see the plumes and in fact I just

1277

01:02:36,500 --> 01:02:32,220

read a paper on that and I think the

1278

01:02:40,460 --> 01:02:36,510

answer is no that is that is what in

1279

01:02:41,870 --> 01:02:40,470

fact Enceladus is locked but Europe is

1280

01:02:43,280 --> 01:02:41,880

not so I think that's one of the other

1281

01:02:46,790 --> 01:02:43,290

pieces of evidence that you we're not

1282

01:02:49,890 --> 01:02:46,800

looking at exactly the same thing in the

1283

01:02:54,310 --> 01:02:49,900

green sweater there yes

1284

01:03:02,350 --> 01:02:54,320

when the bottom I think you said it was

1285

01:03:12,070 --> 01:03:02,360

100 degrees Celsius when it comes I

1286

01:03:13,360 --> 01:03:12,080

would be like a 94 degrees Kelvin no cuz

1287

01:03:15,610 --> 01:03:13,370

you only see it on you only have a

1288

01:03:17,820 --> 01:03:15,620

little bit of 100 degrees Celsius as it

1289

01:03:20,260 --> 01:03:17,830

comes out and then it'll cool and

1290

01:03:24,160 --> 01:03:20,270

remember the ice is a hundred meters is

1291

01:03:53,650 --> 01:03:24,170

a hundred kilometers thick so the the

1292

01:03:57,550 --> 01:03:53,660

surface of Europe is so the question is

1293

01:04:02,530 --> 01:03:57,560

is the temperature on the surface of

1294

01:04:05,920 --> 01:04:02,540

Europa fluid and the answer is I'm not

1295

01:04:07,750 --> 01:04:05,930

sure because it well you know sometimes

1296

01:04:11,050 --> 01:04:07,760

Europe is facing the Sun so it's gonna

1297

01:04:12,700 --> 01:04:11,060

have a little more insulation I think

1298

01:04:19,570 --> 01:04:12,710

overall if we go back and look at those

1299

01:04:23,230 --> 01:04:19,580

beautiful images let's go back and look

1300

01:04:25,930 --> 01:04:23,240

at the numbers let's do the numbers so

1301

01:04:29,310 --> 01:04:25,940

what you see here is that you see it's

1302

01:04:31,870 --> 01:04:29,320

roughly about eighty to ninety degrees

1303

01:04:35,230 --> 01:04:31,880

Kelvin with a little bit maybe getting

1304

01:04:37,900 --> 01:04:35,240

up 230 so I don't know if that means

1305

01:04:41,920 --> 01:04:37,910

it's constantly changing but I think

1306

01:04:43,060 --> 01:04:41,930

it's pretty constrained obviously when

1307

01:04:46,000 --> 01:04:43,070

it's facing the Sun it's gonna be a

1308

01:04:47,410 --> 01:04:46,010

little hotter right yeah your image on

1309

01:04:50,380 --> 01:04:47,420

the right is it says the marked is

1310

01:04:51,460 --> 01:04:50,390

daytime and this is daytime and this is

1311

01:04:53,860 --> 01:04:51,470

nighttime here

1312

01:04:56,530 --> 01:04:53,870

so night so that there's probably a 30

1313

01:04:58,630 --> 01:04:56,540

degree change between the daytime and

1314

01:05:02,680 --> 01:04:58,640

the nighttime I don't I don't know that

1315

01:05:03,069 --> 01:05:02,690

means fluid okay so over here in the

1316

01:05:05,079 --> 01:05:03,079

black do

1317

01:05:06,999 --> 01:05:05,089

sure so generally then what is the

1318

01:05:13,680 --> 01:05:07,009

theory behind why's there's a certain

1319

01:05:18,549 --> 01:05:16,359

so the question is what is our

1320

01:05:21,219 --> 01:05:18,559

understanding of why we only see the

1321

01:05:26,199 --> 01:05:21,229

plumes in one location yeah good

1322

01:05:29,140 --> 01:05:26,209

question that's what we're trying to

1323

01:05:30,849 --> 01:05:29,150

understand actually and isn't that what

1324

01:05:32,680 --> 01:05:30,859

one of the things your rope a clipper

1325

01:05:34,329 --> 01:05:32,690

would be able to Europa clipper we'll be

1326

01:05:37,690 --> 01:05:34,339

able to probe a little better so there

1327

01:05:39,880 --> 01:05:37,700

like there was a question earlier and so

1328

01:05:42,190 --> 01:05:39,890

doing the comparison between Europa and

1329

01:05:44,170 --> 01:05:42,200

say some of the other moons not quite

1330

01:05:47,410 --> 01:05:44,180

seeing a direct analog particularly with

1331

01:05:50,680 --> 01:05:47,420

Enceladus so it is a it is an open

1332

01:05:52,120 --> 01:05:50,690

question and yes having a mission

1333

01:05:54,089 --> 01:05:52,130

actually go there and get really close

1334

01:05:56,229 --> 01:05:54,099

and personal would be a wonderful thing

1335

01:05:57,459 --> 01:05:56,239

right so there was a question on line

1336

01:05:58,749 --> 01:05:57,469

let me just interrupt with that that was

1337

01:06:01,059 --> 01:05:58,759

sort of related to the Europa clipper

1338

01:06:03,729 --> 01:06:01,069

they were wondering what all right so

1339

01:06:05,709 --> 01:06:03,739

they they recognized that like that yes

1340

01:06:07,359 --> 01:06:05,719

you have to go survey what would be the

1341

01:06:09,279 --> 01:06:07,369

time scale for a lander mission is what

1342

01:06:12,099 --> 01:06:09,289

they were asking I mean like when would

1343

01:06:17,759 --> 01:06:12,109

that happen yes if Europa clipper went

1344

01:06:19,660 --> 01:06:17,769

up next next decade would there be the

1345

01:06:21,339 --> 01:06:19,670

several people online were very

1346

01:06:23,049 --> 01:06:21,349

concerned that we need to be able to

1347

01:06:29,229 --> 01:06:23,059

measure the water on Europa before they

1348

01:06:31,349 --> 01:06:29,239

died yeah how old are they and where do

1349

01:06:35,309 --> 01:06:31,359

they live

1350

01:06:39,150 --> 01:06:35,319

I think it's likely within my my my

1351

01:06:41,690 --> 01:06:39,160

lifetime okay and I would hope in 20

1352

01:06:46,200 --> 01:06:44,430

all right so we'll just call it decades

1353

01:06:48,359 --> 01:06:46,210

okay yeah yeah it's not it's not gonna

1354

01:07:04,220 --> 01:06:48,369

happen next decade but I think in the

1355

01:07:08,370 --> 01:07:04,230

thirties would be a reason possible yeah

1356

01:07:10,770 --> 01:07:08,380

there are there are people on the on the

1357

01:07:13,950 --> 01:07:10,780

team that not me because I'm sort of a

1358

01:07:16,140 --> 01:07:13,960

you know lower level type player in this

1359

01:07:20,030 --> 01:07:16,150

but there are people there who have been

1360

01:07:44,760 --> 01:07:20,040

who are very active in talking to NASA

1361

01:07:47,190 --> 01:07:44,770

about that okay that's you the question

1362

01:07:52,020 --> 01:07:47,200

is House Cassini flew through the plumes

1363

01:07:53,970 --> 01:07:52,030

of Enceladus and made some measurements

1364

01:07:56,130 --> 01:07:53,980

of the of the chemistry and so the

1365

01:07:57,539 --> 01:07:56,140

question is if you went through the

1366

01:08:04,079 --> 01:07:57,549

plumes of Europa what would that

1367

01:08:05,789 --> 01:08:04,089

chemistry look like I'm not actually

1368

01:08:08,730 --> 01:08:05,799

sure I know the answer to that I think

1369

01:08:11,990 --> 01:08:08,740

it would depend on well you'd want to

1370

01:08:14,910 --> 01:08:12,000

see some evidence for example like

1371

01:08:17,700 --> 01:08:14,920

hydrogen compounds sulfate compounds

1372

01:08:20,490 --> 01:08:17,710

maybe iron compounds but I don't know

1373

01:08:22,289 --> 01:08:20,500

the quantity of hand would it matter

1374

01:08:24,990 --> 01:08:22,299

that much that Enceladus is sort of a

1375

01:08:28,410 --> 01:08:25,000

medium sized moon whereas Europa is a

1376

01:08:31,530 --> 01:08:28,420

large moon your open one of the seven

1377

01:08:35,479 --> 01:08:31,540

large moons Enceladus is just one of the

1378

01:08:38,160 --> 01:08:35,489

medium one of the many in size moons so

1379

01:08:40,800 --> 01:08:38,170

that's one of the major differences I

1380

01:08:44,010 --> 01:08:40,810

think of those two and then in addition

1381

01:08:51,200 --> 01:08:44,020

the cool thing would be to find

1382

01:08:54,330 --> 01:08:51,210

tyria all right in the back up there we

1383

01:08:55,290 --> 01:08:54,340

knew that there were was like when

1384

01:08:58,370 --> 01:08:55,300

Europe

1385

01:09:01,040 --> 01:08:58,380

what would the implication be for

1386

01:09:13,050 --> 01:09:01,050

because there's life in the solar system

1387

01:09:17,720 --> 01:09:13,060

big deal I think it certainly opens up

1388

01:09:20,910 --> 01:09:17,730

the definition of the habitable zone so

1389

01:09:22,920 --> 01:09:20,920

so the question is what is what is the

1390

01:09:24,510 --> 01:09:22,930

implication if life were found on Europe

1391

01:09:27,210 --> 01:09:24,520

or what is the implication for life in

1392

01:09:28,950 --> 01:09:27,220

the universe in in general so I'm gonna

1393

01:09:32,520 --> 01:09:28,960

back that up a little bit which is that

1394

01:09:36,000 --> 01:09:32,530

on earth wherever there is the

1395

01:09:38,940 --> 01:09:36,010

possibility of life there is life so

1396

01:09:40,260 --> 01:09:38,950

life is very tenacious and you know just

1397

01:09:44,580 --> 01:09:40,270

but just take that you know the basic

1398

01:09:48,290 --> 01:09:44,590

definition of life organic an organism

1399

01:09:51,690 --> 01:09:48,300

that can replicate and eats and poops

1400

01:09:55,520 --> 01:09:51,700

that's the basic definition of life and

1401

01:09:59,720 --> 01:09:58,380

if there's life on Europa that tells you

1402

01:10:03,240 --> 01:09:59,730

that you don't need to have direct

1403

01:10:06,120 --> 01:10:03,250

starlight whether its sunlight or or

1404

01:10:07,440 --> 01:10:06,130

that to provide the energy and that's a

1405

01:10:09,570 --> 01:10:07,450

little different because that's one of

1406

01:10:11,670 --> 01:10:09,580

the difficulties is on earth is knowing

1407

01:10:12,960 --> 01:10:11,680

exactly when you know you're no longer

1408

01:10:15,510 --> 01:10:12,970

dependent on sunlight so if you're in

1409

01:10:17,730 --> 01:10:15,520

the bottom of the ocean with the in the

1410

01:10:19,650 --> 01:10:17,740

trenches is the hydrothermal vents and

1411

01:10:21,420 --> 01:10:19,660

so forth you know you're not getting a

1412

01:10:24,780 --> 01:10:21,430

lot of sunlight down there at all

1413

01:10:27,530 --> 01:10:24,790

so that's a possibility so then when

1414

01:10:29,940 --> 01:10:27,540

people talk about looking for

1415

01:10:31,230 --> 01:10:29,950

extraterrestrial planets and looking for

1416

01:10:32,490 --> 01:10:31,240

evidence of life there's a whole

1417

01:10:35,670 --> 01:10:32,500

discussion of what's considered the

1418

01:10:38,160 --> 01:10:35,680

habitable zone hours some people call it

1419

01:10:41,040 --> 01:10:38,170

the Goldilocks you may have heard of it

1420

01:10:43,410 --> 01:10:41,050

as the Goldilocks a factor which is

1421

01:10:45,360 --> 01:10:43,420

where now you're looking at but there

1422

01:10:48,930 --> 01:10:45,370

you're looking at things like what could

1423

01:10:51,090 --> 01:10:48,940

be an earth as we know as we know Earth

1424

01:10:54,630 --> 01:10:51,100

if there's life on Europa what that

1425

01:10:56,220 --> 01:10:54,640

tells us I think is that the definition

1426

01:10:57,900 --> 01:10:56,230

of a habitable zone you can have one

1427

01:11:00,000 --> 01:10:57,910

four planets but you might also

1428

01:11:02,250 --> 01:11:00,010

to sort of think about all the

1429

01:11:04,860 --> 01:11:02,260

conditions that are necessary going back

1430

01:11:08,100 --> 01:11:04,870

to the basics of energy and chemistry

1431

01:11:09,330 --> 01:11:08,110

that are necessary so I think it opens

1432

01:11:12,420 --> 01:11:09,340

it up I think it also makes it much

1433

01:11:13,920 --> 01:11:12,430

harder to Wow if you're looking for

1434

01:11:16,650 --> 01:11:13,930

moons around Jupiter z-- and extra

1435

01:11:18,990 --> 01:11:16,660

terrestrial planets you'd make an

1436

01:11:21,270 --> 01:11:19,000

exoplanets it's a more difficult to find

1437

01:11:23,610 --> 01:11:21,280

but I think it would imply that it's

1438

01:11:25,350 --> 01:11:23,620

probably more prevalent this is now my

1439

01:11:28,380 --> 01:11:25,360

personal opinion it's more prevalent

1440

01:11:30,360 --> 01:11:28,390

than we might otherwise have expected

1441

01:11:34,110 --> 01:11:30,370

it's a long-winded answer to a short

1442

01:11:38,940 --> 01:11:34,120

question all right other questions

1443

01:11:44,160 --> 01:11:38,950

Peter another source of heat for Europa

1444

01:11:45,980 --> 01:11:44,170

like radioactivity so the question is

1445

01:11:49,970 --> 01:11:45,990

could there be another source of heat

1446

01:11:54,390 --> 01:11:49,980

like radioactivity from the core

1447

01:11:56,730 --> 01:11:54,400

probably but you know these let's say

1448

01:12:00,000 --> 01:11:56,740

these formed four-and-a-half billion

1449

01:12:03,210 --> 01:12:00,010

years ago four billion years ago I don't

1450

01:12:04,740 --> 01:12:03,220

think it would be enough I think you

1451

01:12:18,540 --> 01:12:04,750

would definitely need the title heating

1452

01:12:20,550 --> 01:12:18,550

to to keep that ocean liquid some of the

1453

01:12:23,010 --> 01:12:20,560

numbers I've seen like six to ten times

1454

01:12:27,330 --> 01:12:23,020

the amount of water on earth it's a huge

1455

01:13:01,250 --> 01:12:27,340

amount of water hey was there a question

1456

01:13:04,770 --> 01:13:01,260

in the back there other questions no I I

1457

01:13:08,280 --> 01:13:04,780

think it's possible it's probably less

1458

01:13:10,380 --> 01:13:08,290

likely yes tardigrades are very

1459

01:13:15,600 --> 01:13:10,390

tenacious and they are very tough

1460

01:13:17,370 --> 01:13:15,610

they're really hard to to do away with I

1461

01:13:20,700 --> 01:13:17,380

mean they're used in school in school

1462

01:13:39,680 --> 01:13:20,710

labs all the time because of that so

1463

01:14:06,870 --> 01:13:55,590

survive cosmic radiation but they are

1464

01:14:08,370 --> 01:14:06,880

multicellular yeah you if you don't know

1465

01:14:11,690 --> 01:14:08,380

about tardigrades you might want to look

1466

01:14:14,430 --> 01:14:11,700

them up my son at one of the science

1467

01:14:16,020 --> 01:14:14,440

centers we went to spend about half an

1468

01:14:20,160 --> 01:14:16,030

hour reading about the tardigrades and

1469

01:14:23,370 --> 01:14:20,170

it's really cool tardigrades are used

1470

01:14:24,690 --> 01:14:23,380

for in a lot of astrobiology labs when

1471

01:14:25,830 --> 01:14:24,700

they when they teach astrobiology

1472

01:14:28,920 --> 01:14:25,840

because it's one of those life forms

1473

01:14:35,220 --> 01:14:28,930

that is very tough and it you can

1474

01:14:48,229 --> 01:14:40,009

[Laughter]

1475

01:14:49,759 --> 01:14:48,239

they're everywhere okay questions you've

1476

01:15:11,540 --> 01:14:49,769

had want to see if there's any other

1477

01:15:14,089 --> 01:15:11,550

okay back to you relationships so the so

1478

01:15:17,930 --> 01:15:14,099

the question is the fact that Jupiter is

1479

01:15:20,390 --> 01:15:17,940

a cat is a gaseous planet yeah because

1480

01:15:22,879 --> 01:15:20,400

that effect in the gravitational

1481

01:15:35,120 --> 01:15:22,889

relationship between the planet and its

1482

01:15:38,660 --> 01:15:35,130

moon because of the density yes yes it's

1483

01:15:42,169 --> 01:15:38,670

yes or no because if it's just gravity

1484

01:15:45,979 --> 01:15:42,179

then mass is more important than the

1485

01:15:48,229 --> 01:15:45,989

density so it's a total mass but the

1486

01:15:49,939 --> 01:15:48,239

fact that it has an atmosphere and has a

1487

01:15:52,669 --> 01:15:49,949

magnetic field so you start seeing

1488

01:15:56,899 --> 01:15:52,679

interactions of the magnetic field with

1489

01:15:59,709 --> 01:15:56,909

of Jupiter with its with its um plus the

1490

01:16:02,779 --> 01:15:59,719

the aurora which already you know it's a

1491

01:16:04,580 --> 01:16:02,789

it's a chemical reaction at a coming

1492

01:16:08,629 --> 01:16:04,590

it's a physical reaction so you you're

1493

01:16:10,100 --> 01:16:08,639

getting particles thrown into the

1494

01:16:12,890 --> 01:16:10,110

magnetic field so that will that will

1495

01:16:14,660 --> 01:16:12,900

affect so you could you can get

1496

01:16:17,029 --> 01:16:14,670

sputtering for example on the surface of

1497

01:16:18,890 --> 01:16:17,039

the of the moons that's when material

1498

01:16:22,040 --> 01:16:18,900

gets bombarded and then gets but gets

1499

01:16:28,729 --> 01:16:22,050

some sort of scraped off so the answer

1500

01:16:34,680 --> 01:16:28,739

is yes to both okay Herman okay

1501

01:16:44,259 --> 01:16:41,129

eating the course I don't think so no

1502

01:16:47,799 --> 01:16:44,269

all right so thank you all for coming on

1503

01:16:50,439 --> 01:16:47,809

next month may 1st gravitational wave

1504

01:16:56,590 --> 01:16:50,449

astronomy with Annie Fructis give