

1
00:00:00,000 --> 00:00:04,440
joy to be your host I am dr. Frank

2
00:00:02,040 --> 00:00:07,799
summers of the office of public outreach

3
00:00:04,440 --> 00:00:10,260
and we have an amazing audience here for

4
00:00:07,799 --> 00:00:13,650
you tonight Bonnie Saturn really sells

5
00:00:10,259 --> 00:00:16,259
okay so we have a packed house here

6
00:00:13,650 --> 00:00:18,660
tonight we may not have anymore we have

7
00:00:16,260 --> 00:00:19,920
a couple lithographs down here we

8
00:00:18,660 --> 00:00:23,160
started out giving out the monkey head

9
00:00:19,920 --> 00:00:25,439
nebula we sold out of the monkey head we

10
00:00:23,160 --> 00:00:27,778
had to go to the 30 Doradus which is

11
00:00:25,439 --> 00:00:28,920
also known as the tarantula nebula so if

12
00:00:27,778 --> 00:00:30,960
you didn't get monkeys you got

13
00:00:28,920 --> 00:00:32,759
tarantulas okay and if you're afraid of

14
00:00:30,960 --> 00:00:35,370
spiders well I'm sorry that's all we

15
00:00:32,759 --> 00:00:38,909
have left please come down and grab one

16
00:00:35,369 --> 00:00:44,909
if you didn't on the way in our talk do

17
00:00:38,909 --> 00:00:50,488
I even need to say tonight on our talk

18
00:00:44,909 --> 00:00:53,159
is Cassini's grand finale at saturn and

19
00:00:50,488 --> 00:00:55,288
we've been only waiting 19 years and 11

20
00:00:53,159 --> 00:00:57,948
months for this because that's what

21
00:00:55,289 --> 00:01:00,510
Cassini launched 19 years 11 months ago

22
00:00:57,948 --> 00:01:03,570
absolutely looking forward to it should

23
00:01:00,509 --> 00:01:06,060
it's a lot of fun upcoming next month

24
00:01:03,570 --> 00:01:09,900
Elizabeth Tasker from the Japan

25
00:01:06,060 --> 00:01:12,740
aerospace exploration agency she'll be

26
00:01:09,900 --> 00:01:16,380
coming in and talking about dangerous

27
00:01:12,739 --> 00:01:19,739
worlds yes exoplanets and such all right

28
00:01:16,379 --> 00:01:24,209
and you can see our familiar TBA coming

29

00:01:19,739 --> 00:01:26,399
in in December in January which means I

30
00:01:24,209 --> 00:01:29,039
was working on some stuff for the end of

31
00:01:26,400 --> 00:01:31,759
the fiscal year and didn't nag people to

32
00:01:29,040 --> 00:01:33,868
sign up for talks actually I have one

33
00:01:31,759 --> 00:01:36,118
scheduled for January but we may have to

34
00:01:33,868 --> 00:01:41,310
change that I don't know with the news

35
00:01:36,118 --> 00:01:43,549
so anyways okay so on some of the ninth

36
00:01:41,310 --> 00:01:48,030
great we can do it on the night okay

37
00:01:43,549 --> 00:01:49,740
okay ooh tag team on the 9th okay we

38
00:01:48,030 --> 00:01:51,629
have still have some there's a couple

39
00:01:49,739 --> 00:01:52,769
extra seats down here if the folks

40
00:01:51,629 --> 00:01:55,259
you're standing in the corner would like

41
00:01:52,769 --> 00:01:56,968
to if you have a seat next to you raise

42
00:01:55,259 --> 00:01:58,859
your hand so these guys can don't have

43
00:01:56,968 --> 00:02:03,629

to stand for the whole whole night okay

44

00:01:58,859 --> 00:02:05,459

all right let's see website if you go if

45

00:02:03,629 --> 00:02:07,890

you use your favorite search engine and

46

00:02:05,459 --> 00:02:10,109

look for Hubble public talks you'll find

47

00:02:07,890 --> 00:02:12,930

this page with the list of the upcoming

48

00:02:10,110 --> 00:02:13,480

lectures the links to watching it live

49

00:02:12,930 --> 00:02:17,409

on

50

00:02:13,479 --> 00:02:19,359

as well as in the archive and the boxes

51

00:02:17,409 --> 00:02:22,030

where you can subscribe or even

52

00:02:19,360 --> 00:02:24,069

unsubscribe to our mailing list and get

53

00:02:22,030 --> 00:02:26,620

the monthly reminders of the talks and

54

00:02:24,068 --> 00:02:28,929

actually also we send out the monthly

55

00:02:26,620 --> 00:02:30,580

listings of where is on the webcasts

56

00:02:28,930 --> 00:02:33,040

okay

57

00:02:30,580 --> 00:02:34,870

announcements sign up at the website or

58
00:02:33,039 --> 00:02:36,579
you just give me your email address and

59
00:02:34,870 --> 00:02:39,519
if you have comments or questions you

60
00:02:36,580 --> 00:02:43,290
can send them to public lecture at STScI

61
00:02:39,519 --> 00:02:45,459
dot edu if you would like social media

62
00:02:43,289 --> 00:02:47,889
we have Facebook Twitter YouTube

63
00:02:45,459 --> 00:02:50,469
Instagram and maybe a few more things

64
00:02:47,889 --> 00:02:52,750
that I'm not haven't listed here I

65
00:02:50,469 --> 00:02:55,870
myself I'm on Facebook Google+ and

66
00:02:52,750 --> 00:02:57,459
Twitter every now and then and have a

67
00:02:55,870 --> 00:03:00,069
blog on Hubbell site if you want to

68
00:02:57,459 --> 00:03:02,049
follow me the observatory

69
00:03:00,068 --> 00:03:04,750
yes the weather appears to be permitting

70
00:03:02,049 --> 00:03:07,450
tonight and ireenie sent me a text and

71
00:03:04,750 --> 00:03:10,150
said yes she will be doing it so we will

72
00:03:07,449 --> 00:03:12,789
be meeting at that door over there okay

73
00:03:10,150 --> 00:03:15,069
now unfortunately and it's really hard

74
00:03:12,789 --> 00:03:19,269
to tell an audience of this size she can

75
00:03:15,068 --> 00:03:21,068
only take 15 to 20 people over okay and

76
00:03:19,269 --> 00:03:24,939
I know there's like 200 of you here

77
00:03:21,068 --> 00:03:26,979
tonight so if you have been before

78
00:03:24,939 --> 00:03:28,810
please let somebody else who hasn't been

79
00:03:26,979 --> 00:03:32,169
and if you don't get to go tonight

80
00:03:28,810 --> 00:03:33,909
please come back and and you will be

81
00:03:32,169 --> 00:03:37,929
able to do it after another lecture or

82
00:03:33,909 --> 00:03:40,479
you can go to MD dot space grant o RG

83
00:03:37,930 --> 00:03:43,599
find this webpage and they have open

84
00:03:40,479 --> 00:03:46,298
houses most every Friday evening okay

85
00:03:43,599 --> 00:03:49,060
they update this web page at like 6:00

86

00:03:46,299 --> 00:03:50,620
p.m. or 5 or 6 p.m. on Friday to tell

87
00:03:49,060 --> 00:03:52,959
you whether or not it will be open and

88
00:03:50,620 --> 00:03:54,759
you will get a longer observing session

89
00:03:52,959 --> 00:03:57,670
at their open house then you will get

90
00:03:54,759 --> 00:03:59,888
after the lecture here okay and as we're

91
00:03:57,669 --> 00:04:04,089
going into fall we've just passed the

92
00:03:59,889 --> 00:04:06,370
equinox the nights get longer and so

93
00:04:04,090 --> 00:04:10,569
lots and lots of observing is possible

94
00:04:06,370 --> 00:04:15,090
okay all right and now my part news from

95
00:04:10,568 --> 00:04:18,598
the universe for October 2017

96
00:04:15,090 --> 00:04:21,500
unfortunately the top story tonight is

97
00:04:18,598 --> 00:04:23,689
JWST launch delay

98
00:04:21,500 --> 00:04:30,139
no no no you got to do that all together

99
00:04:23,689 --> 00:04:32,779
one two three thank you okay so this is

100
00:04:30,139 --> 00:04:35,990

the Jay this is a drawing of the James

101

00:04:32,779 --> 00:04:39,889

Webb Space Telescope it will be NASA's

102

00:04:35,990 --> 00:04:42,769

next great Observatory it is an infrared

103

00:04:39,889 --> 00:04:46,610

telescope with a six and a half meter

104

00:04:42,769 --> 00:04:49,339

mirror 18 segments it will be launched

105

00:04:46,610 --> 00:04:52,069

and go out a million miles from Earth so

106

00:04:49,339 --> 00:04:53,299

it is nice and cool and away from the

107

00:04:52,069 --> 00:04:55,040

influence of Earth

108

00:04:53,300 --> 00:04:57,290

it'll have these great Sun shields to

109

00:04:55,040 --> 00:04:59,390

also keep it cool it will do amazing

110

00:04:57,290 --> 00:05:02,600

things it will do things Hubble cannot

111

00:04:59,389 --> 00:05:04,969

do but it won't do them on the time

112

00:05:02,600 --> 00:05:08,290

scale we had hoped it would do them okay

113

00:05:04,970 --> 00:05:12,470

it was slated to launch in October 2018

114

00:05:08,290 --> 00:05:15,050

that is no longer the launch date NASA

115
00:05:12,470 --> 00:05:17,150
had a press release last week and I'm

116
00:05:15,050 --> 00:05:18,530
quoting from it it says is now is

117
00:05:17,149 --> 00:05:22,310
planning to launch between March and

118
00:05:18,529 --> 00:05:24,769
June of 2019 so it's about a six months

119
00:05:22,310 --> 00:05:26,839
slip in the schedule it is not

120
00:05:24,769 --> 00:05:28,459
indicative of hardware or technical

121
00:05:26,839 --> 00:05:30,369
performance concerns they want to make

122
00:05:28,459 --> 00:05:32,870
sure that look everything's going fine

123
00:05:30,370 --> 00:05:35,030
we just want to make sure it's perfect

124
00:05:32,870 --> 00:05:38,269
because unlike Hubble we can't go out

125
00:05:35,029 --> 00:05:39,829
and service this okay so integration of

126
00:05:38,269 --> 00:05:42,379
the various spacecraft elements is

127
00:05:39,829 --> 00:05:44,240
taking longer than expected all right

128
00:05:42,379 --> 00:05:47,540
and they want to make sure they do it

129
00:05:44,240 --> 00:05:49,759
right and one other thing in terms of

130
00:05:47,540 --> 00:05:52,280
the financials the existing program

131
00:05:49,759 --> 00:05:54,500
budget accommodates the change in launch

132
00:05:52,279 --> 00:05:57,349
date so you as taxpayers are not going

133
00:05:54,500 --> 00:05:59,569
to pay extra for this delay it's all

134
00:05:57,350 --> 00:06:02,419
within the program budget they build a

135
00:05:59,569 --> 00:06:04,728
lot of contingencies into these plans

136
00:06:02,418 --> 00:06:07,329
and unfortunately that we've had to add

137
00:06:04,728 --> 00:06:10,490
take take one of those contingencies so

138
00:06:07,329 --> 00:06:13,639
instead of October 2018 we're looking

139
00:06:10,490 --> 00:06:15,620
between March and June of 2019 it will

140
00:06:13,639 --> 00:06:19,189
be worth it though okay

141
00:06:15,620 --> 00:06:25,370
it really will all right our second

142
00:06:19,189 --> 00:06:26,839
story a tale of two comets yes I know I

143

00:06:25,370 --> 00:06:29,478
didn't quite come up with a real

144
00:06:26,839 --> 00:06:31,429
Dickensian story to go here but I just

145
00:06:29,478 --> 00:06:33,680
like the title alright so first of all

146
00:06:31,430 --> 00:06:34,709
what we're talking about here is the

147
00:06:33,680 --> 00:06:37,500
asteroid belt

148
00:06:34,709 --> 00:06:40,109
okay this is the orbit of Jupiter out

149
00:06:37,500 --> 00:06:41,670
here and in here we have in the center

150
00:06:40,110 --> 00:06:44,310
we have the orbits of Mercury Venus

151
00:06:41,670 --> 00:06:46,290
Earth and Mars in between where you see

152
00:06:44,310 --> 00:06:49,740
all these green things and the red

153
00:06:46,290 --> 00:06:52,620
things those are the main belt asteroids

154
00:06:49,740 --> 00:06:57,090
there are several hundred thousand of

155
00:06:52,620 --> 00:07:00,480
these asteroids however also in that

156
00:06:57,089 --> 00:07:03,750
area are a lot of comets a lot of short

157
00:07:00,480 --> 00:07:09,170

period comets and we're gonna talk about

158

00:07:03,750 --> 00:07:13,410

an object that is actually both here so

159

00:07:09,170 --> 00:07:17,129

in November 2006 they discovered an

160

00:07:13,410 --> 00:07:18,540

asteroid and they called it 2006 VW 139

161

00:07:17,129 --> 00:07:20,550

that's thus the standard nomenclature

162

00:07:18,540 --> 00:07:22,980

that we give to asteroids when we

163

00:07:20,550 --> 00:07:26,490

discover them and then they observed the

164

00:07:22,980 --> 00:07:30,090

same object in November 2011 and they

165

00:07:26,490 --> 00:07:32,759

found that it had a tail and tails

166

00:07:30,089 --> 00:07:35,219

indicate that it's a comet so they also

167

00:07:32,759 --> 00:07:37,829

gave it the designation of Comet two

168

00:07:35,220 --> 00:07:40,950

eight eight P alright so it had both

169

00:07:37,829 --> 00:07:43,469

asteroid designations and comet a comet

170

00:07:40,949 --> 00:07:45,329

designation well that's obviously an

171

00:07:43,470 --> 00:07:47,610

interesting object so what are you gonna

172
00:07:45,329 --> 00:07:50,189
do you're gonna take Hubble and you're

173
00:07:47,610 --> 00:07:54,449
gonna look at it and Hubble looked at it

174
00:07:50,189 --> 00:07:59,370
in August of 2016 and Hubble saw this

175
00:07:54,449 --> 00:08:02,879
ooh what do we see we see in the center

176
00:07:59,370 --> 00:08:05,879
not one but two bright spots in the

177
00:08:02,879 --> 00:08:10,860
center so as you can see I've updated it

178
00:08:05,879 --> 00:08:12,360
to be a binary asteroid 2006 WV 139 and

179
00:08:10,860 --> 00:08:15,780
I guess you could call it a double

180
00:08:12,360 --> 00:08:18,509
nucleus comet two eight eight P we have

181
00:08:15,779 --> 00:08:20,549
an object that appears to be two objects

182
00:08:18,509 --> 00:08:23,909
now in examining it and trying to

183
00:08:20,550 --> 00:08:26,430
understand it they estimate that it was

184
00:08:23,910 --> 00:08:29,880
a single object that broke apart about

185
00:08:26,430 --> 00:08:33,149
five thousand years ago and then the

186
00:08:29,879 --> 00:08:35,340
gases that are exposed caused jets and

187
00:08:33,149 --> 00:08:39,419
then the two pieces moved away from each

188
00:08:35,340 --> 00:08:43,410
other okay that also produced material

189
00:08:39,419 --> 00:08:46,019
that streams out as this tail so Hubble

190
00:08:43,409 --> 00:08:47,009
looked at it not just once but five

191
00:08:46,019 --> 00:08:50,870
times

192
00:08:47,009 --> 00:08:54,799
and we looked at in September first in

193
00:08:50,870 --> 00:08:58,590
September ninth in September 20th and

194
00:08:54,799 --> 00:09:01,349
September 29th and what do we see we see

195
00:08:58,590 --> 00:09:04,649
the tail wagging okay

196
00:09:01,350 --> 00:09:07,230
yes comets wag their tails right so here

197
00:09:04,649 --> 00:09:09,629
are those five images but you can see

198
00:09:07,230 --> 00:09:12,930
they only occur over this time scale of

199
00:09:09,629 --> 00:09:15,269
about a month now some of the change of

200

00:09:12,929 --> 00:09:19,709
the orientation of the tail is due to

201
00:09:15,269 --> 00:09:22,049
the geometry of Earth and and the comet

202
00:09:19,710 --> 00:09:23,730
or asteroid as it was but over the

203
00:09:22,049 --> 00:09:27,599
course of a month it wouldn't change

204
00:09:23,730 --> 00:09:30,029
that far so what they really think that

205
00:09:27,600 --> 00:09:33,149
it's also due to different types of

206
00:09:30,029 --> 00:09:37,019
particles being emitted the larger

207
00:09:33,149 --> 00:09:39,000
particles are here these are on order

208
00:09:37,019 --> 00:09:41,399
millimeter sized when I say large we're

209
00:09:39,000 --> 00:09:43,980
talking tiny tiny dust particles okay

210
00:09:41,399 --> 00:09:45,779
this is a dust tail a tiny tiny dust

211
00:09:43,980 --> 00:09:48,240
pyloric is about one millimeter those

212
00:09:45,779 --> 00:09:51,089
are large in astronomical terms here oh

213
00:09:48,240 --> 00:09:53,039
one millimeter in size are blowing off

214
00:09:51,090 --> 00:09:57,170

in this direction due to how they're

215

00:09:53,039 --> 00:10:00,209
being ejected but by this time the

216

00:09:57,169 --> 00:10:03,209
emission the dust was mostly very very

217

00:10:00,210 --> 00:10:06,300
small about 1/100 that size or 10

218

00:10:03,210 --> 00:10:08,370
microns and those 10 micron particles

219

00:10:06,299 --> 00:10:10,859
get actually pushed back by the

220

00:10:08,370 --> 00:10:13,049
radiation pressure of the Sun and so

221

00:10:10,860 --> 00:10:15,539
here is where the tail is actually

222

00:10:13,049 --> 00:10:18,809
pointing away from the Sun like a normal

223

00:10:15,539 --> 00:10:21,000
Comet dust tail does and here is it's

224

00:10:18,809 --> 00:10:23,639
not quite pointing away from the Sun due

225

00:10:21,000 --> 00:10:26,669
to the larger particles in it so we have

226

00:10:23,639 --> 00:10:30,809
a really cool object that's part

227

00:10:26,669 --> 00:10:35,639
asteroid part comet and it's able to wag

228

00:10:30,809 --> 00:10:38,759
its own tail kind of cool all right our

229
00:10:35,639 --> 00:10:44,039
final story for you is candles in the

230
00:10:38,759 --> 00:10:47,189
dark now candles is an acronym for a

231
00:10:44,039 --> 00:10:49,919
cosmic assembly deep extra galactic

232
00:10:47,190 --> 00:10:53,790
legacy survey blah blah blah what it

233
00:10:49,919 --> 00:10:55,829
really is is a huge project to study the

234
00:10:53,789 --> 00:11:00,539
development gap of galaxies over time

235
00:10:55,830 --> 00:11:03,990
they got more orbits on Hubble than any

236
00:11:00,539 --> 00:11:05,959
their project in history over 900 Hubble

237
00:11:03,990 --> 00:11:08,789
orbits and they looked at five different

238
00:11:05,960 --> 00:11:11,280
fields looking very deep into these

239
00:11:08,789 --> 00:11:13,949
fields alright and here's one of them

240
00:11:11,279 --> 00:11:17,759
it's called the ultra deep survey and

241
00:11:13,950 --> 00:11:20,370
this is filled with about twenty thirty

242
00:11:17,759 --> 00:11:23,789
thousand galaxies okay and these

243
00:11:20,370 --> 00:11:27,330
galaxies are spread out across across

244
00:11:23,789 --> 00:11:30,779
space but as we look out into space

245
00:11:27,330 --> 00:11:32,370
we're also looking back into time if you

246
00:11:30,779 --> 00:11:35,100
look a billion years out into space

247
00:11:32,370 --> 00:11:38,580
you're seeing that galaxy as it was a

248
00:11:35,100 --> 00:11:40,259
billion years ago if you go three

249
00:11:38,580 --> 00:11:44,310
billion years that's three billion years

250
00:11:40,259 --> 00:11:47,039
ago some of these galaxies are 10 11 12

251
00:11:44,309 --> 00:11:50,009
billion light years away so we're seeing

252
00:11:47,039 --> 00:11:53,309
them as they were 10 11 12 billion years

253
00:11:50,009 --> 00:11:55,710
ago by statistically looking at those

254
00:11:53,309 --> 00:11:58,500
galaxies at different distances we can

255
00:11:55,710 --> 00:12:00,780
assemble a view of galaxies as they were

256
00:11:58,500 --> 00:12:04,649
at different state ages of the universe

257

00:12:00,779 --> 00:12:08,129
which gives us a picture of how galaxies

258
00:12:04,649 --> 00:12:09,899
development so they gave us this data in

259
00:12:08,129 --> 00:12:11,250
the office of public outreach and we

260
00:12:09,899 --> 00:12:13,829
said well the first thing we want to do

261
00:12:11,250 --> 00:12:16,470
is we want to show people those galaxies

262
00:12:13,830 --> 00:12:19,290
at different distances so we created a

263
00:12:16,470 --> 00:12:21,690
visualization by cutting out into

264
00:12:19,289 --> 00:12:23,189
cutting out every one of those twenty

265
00:12:21,690 --> 00:12:27,420
six thousand three hundred and four

266
00:12:23,190 --> 00:12:29,400
galaxies in the catalog and then placing

267
00:12:27,419 --> 00:12:32,370
them into a computer model at their

268
00:12:29,399 --> 00:12:34,049
correct relative distances now we didn't

269
00:12:32,370 --> 00:12:36,210
put them at their absolute correct

270
00:12:34,049 --> 00:12:37,979
distances because then it would be so

271
00:12:36,210 --> 00:12:40,170

long that the fly-through would take

272

00:12:37,980 --> 00:12:42,450

probably two hours to do we want to do

273

00:12:40,169 --> 00:12:45,779

it in a minute or so so we compress them

274

00:12:42,450 --> 00:12:50,670

in the Z direction but we do have a

275

00:12:45,779 --> 00:12:52,889

relatively scientific the relative

276

00:12:50,669 --> 00:12:55,529

distances are all proper between the

277

00:12:52,889 --> 00:12:58,590

various galaxies okay can we take the

278

00:12:55,529 --> 00:13:01,169

lights down so people can see this cuz

279

00:12:58,590 --> 00:13:05,310

there's a lot of black here take the

280

00:13:01,169 --> 00:13:08,789

lights down there we go that look better

281

00:13:05,309 --> 00:13:10,889

to you guys okay and so here we have the

282

00:13:08,789 --> 00:13:14,329

the visualization of the candles

283

00:13:10,889 --> 00:13:14,330

ultra-deep survey field

284

00:14:35,870 --> 00:14:40,470

so that was our experiential

285

00:14:38,129 --> 00:14:42,419

visualization for the candles

286
00:14:40,470 --> 00:14:43,830
alternative survey we also plan on doing

287
00:14:42,419 --> 00:14:46,469
some didactic ones where we'll have

288
00:14:43,830 --> 00:14:47,879
narration and point out some of the the

289
00:14:46,470 --> 00:14:49,860
really cool features of it are the

290
00:14:47,879 --> 00:14:52,919
scientific features of it do we have a

291
00:14:49,860 --> 00:14:57,539
question there you are travelling in a

292
00:14:52,919 --> 00:14:58,469
straight line there was some steering in

293
00:14:57,539 --> 00:15:00,209
a straight line

294
00:14:58,470 --> 00:15:02,279
I actually choreographed the camera to

295
00:15:00,210 --> 00:15:04,350
fly up near that one white galaxy then

296
00:15:02,279 --> 00:15:06,629
down through that cluster that swooped

297
00:15:04,350 --> 00:15:08,279
through to those three red galaxies so

298
00:15:06,629 --> 00:15:09,899
that you would said add something that's

299
00:15:08,279 --> 00:15:13,429
and I sort of thought of it as a

300
00:15:09,899 --> 00:15:13,429
rollercoaster ride through galaxies

301
00:15:13,940 --> 00:15:20,370
you're traveling about 13 billion light

302
00:15:16,980 --> 00:15:21,720
years in a minute and 13 seconds so

303
00:15:20,370 --> 00:15:31,019
you're violating every known law of

304
00:15:21,720 --> 00:15:33,389
physics object that you saw there is a

305
00:15:31,019 --> 00:15:35,939
galaxy we cleaned out all the stars and

306
00:15:33,389 --> 00:15:37,740
all the other artifacts from it and we

307
00:15:35,940 --> 00:15:39,600
were left with twenty-six thousand three

308
00:15:37,740 --> 00:15:41,460
hundred four galaxies for which we had

309
00:15:39,600 --> 00:15:44,279
both an image and a measured or

310
00:15:41,460 --> 00:15:52,620
estimated redshift from the scientific

311
00:15:44,279 --> 00:15:55,589
team that's a great question so at the

312
00:15:52,620 --> 00:15:57,690
end there we went to black we got to the

313
00:15:55,590 --> 00:15:59,700
end of the data set we got to the

314

00:15:57,690 --> 00:16:02,310
greatest distance that Hubble can see

315
00:15:59,700 --> 00:16:05,009
because the galaxies further than that

316
00:16:02,309 --> 00:16:09,469
their light is redshifted into the

317
00:16:05,009 --> 00:16:09,470
infrared and Hubble can't see them

318
00:16:13,058 --> 00:16:17,708
okay one of the reasons we want the Jo

319
00:16:14,979 --> 00:16:20,739
is T is to look deeper into the universe

320
00:16:17,708 --> 00:16:22,718
because the light from those galaxies

321
00:16:20,739 --> 00:16:24,009
isn't the infrared and jaidev's t we'll

322
00:16:22,719 --> 00:16:26,129
be able to see the what's similar

323
00:16:24,009 --> 00:16:29,678
resolution to what Hubble has alright

324
00:16:26,129 --> 00:16:32,379
okay now let's go to our featured

325
00:16:29,678 --> 00:16:36,338
speaker tonight our speaker tonight is

326
00:16:32,379 --> 00:16:39,308
Bonnie bunkie she joined us about five

327
00:16:36,339 --> 00:16:41,459
years ago and she has been in the office

328
00:16:39,308 --> 00:16:45,519

of public outreach ever since that time

329

00:16:41,458 --> 00:16:48,008

but about a month ago she got a new

330

00:16:45,519 --> 00:16:49,658

position she in the office of public

331

00:16:48,009 --> 00:16:51,969

outreach she was one of the liaisons

332

00:16:49,658 --> 00:16:53,828

with the J diversity team she's now

333

00:16:51,969 --> 00:16:57,219

moved over to the Jade Ernestine Mission

334

00:16:53,828 --> 00:16:59,649

office team and is now a liaison oh so

335

00:16:57,219 --> 00:17:02,859

she just jumped over the fence and it's

336

00:16:59,649 --> 00:17:05,499

working with them she is an expert in

337

00:17:02,859 --> 00:17:08,350

SAP and on Saturday and she will here

338

00:17:05,499 --> 00:17:12,009

tonight having done her PhD at the

339

00:17:08,349 --> 00:17:14,408

University of Colorado yes and having

340

00:17:12,009 --> 00:17:17,318

worked at the fleet Reuben H fleet

341

00:17:14,409 --> 00:17:19,480

Science Center yes she didn't give me a

342

00:17:17,318 --> 00:17:21,928

biography she was late to come here so

343
00:17:19,480 --> 00:17:29,319
you have to do this remember

344
00:17:21,929 --> 00:17:32,000
she's overall a wonderful person ladies

345
00:17:29,319 --> 00:17:40,730
please welcome dr. Bonnie Mikey

346
00:17:32,000 --> 00:17:44,880
[Applause]

347
00:17:40,730 --> 00:17:48,630
hi everybody I am overwhelmed and a

348
00:17:44,880 --> 00:17:51,810
little intimidated by the audience no

349
00:17:48,630 --> 00:17:55,850
pressure and lots of familiar faces I'm

350
00:17:51,809 --> 00:18:00,569
very happy to see them I yes so Cassini

351
00:17:55,849 --> 00:18:02,609
sadly just ended how many people tuned

352
00:18:00,569 --> 00:18:05,029
in for some of the big events

353
00:18:02,609 --> 00:18:08,639
surrounding the grand finale

354
00:18:05,029 --> 00:18:27,990
alright lots of Saturn files out there I

355
00:18:08,640 --> 00:18:30,150
have no idea what's going on and yeah so

356
00:18:27,990 --> 00:18:33,089
like Frank said this this is a mission

357
00:18:30,150 --> 00:18:37,350
that launched almost 20 years ago it was

358
00:18:33,089 --> 00:18:39,359
October 15 1997 there are people in the

359
00:18:37,349 --> 00:18:46,250
audience that were even alive then I

360
00:18:39,359 --> 00:18:50,399
suspect there then it got to Saturn in

361
00:18:46,250 --> 00:18:52,289
2004 and I remember when that happened I

362
00:18:50,400 --> 00:18:54,710
was a fresh-faced grad student and I

363
00:18:52,289 --> 00:18:57,240
thought hey this is gonna be my mission

364
00:18:54,710 --> 00:18:59,279
and I kind of can't believe that it's

365
00:18:57,240 --> 00:19:02,309
already at its end thirteen years after

366
00:18:59,279 --> 00:19:05,940
that but one of the really amazing

367
00:19:02,309 --> 00:19:08,039
things about the Cassini mission is that

368
00:19:05,940 --> 00:19:10,620
it didn't just change our view of Saturn

369
00:19:08,039 --> 00:19:15,899
it changed our view of our solar system

370
00:19:10,619 --> 00:19:19,139
and of solar systems everywhere so I'm

371

00:19:15,900 --> 00:19:21,000
gonna walk you through the grand finale

372
00:19:19,140 --> 00:19:25,530
and the tour of everything Cassini

373
00:19:21,000 --> 00:19:28,200
learned as a way to bridge to the other

374
00:19:25,529 --> 00:19:31,410
types of planetary science that we now

375
00:19:28,200 --> 00:19:35,069
know about care about are dedicated to

376
00:19:31,410 --> 00:19:36,840
studying okay and I'm gonna cut to the

377
00:19:35,069 --> 00:19:38,669
chase I'm just gonna go ahead and lay it

378
00:19:36,839 --> 00:19:42,539
all on the table the biggest discoveries

379
00:19:38,670 --> 00:19:43,769
of the Cassini mission icy moons we knew

380
00:19:42,539 --> 00:19:46,799
about a whole bunch of them before we

381
00:19:43,769 --> 00:19:49,700
got there we discovered more and we

382
00:19:46,799 --> 00:19:52,450
discovered of the ones that we already

383
00:19:49,700 --> 00:19:55,519
new really amazing cool new things

384
00:19:52,450 --> 00:19:57,259
planetary rings of course we knew about

385
00:19:55,519 --> 00:19:58,909

Saturn's rings it's the ringed planet

386

00:19:57,259 --> 00:20:01,609

everybody knows about this

387

00:19:58,909 --> 00:20:05,840

Galileo studied it and thought it was

388

00:20:01,609 --> 00:20:07,879

amazing we've learned a whole lot of new

389

00:20:05,839 --> 00:20:10,339

stuff in the last 13 years about those

390

00:20:07,880 --> 00:20:13,789

planetary rings that we didn't know you

391

00:20:10,339 --> 00:20:15,678

know a decade ago and then finally to

392

00:20:13,788 --> 00:20:17,179

plant it itself I think that the Rings

393

00:20:15,679 --> 00:20:19,250

and the moons get so much attention that

394

00:20:17,179 --> 00:20:22,070

the actual planet itself gets ignored in

395

00:20:19,250 --> 00:20:25,220

some ways but it has all kinds of storms

396

00:20:22,069 --> 00:20:29,798

big hurricanes all kinds of wind

397

00:20:25,220 --> 00:20:34,278

patterns really some interesting things

398

00:20:29,798 --> 00:20:37,089

so those those are those from you know a

399

00:20:34,278 --> 00:20:39,880

geologist is excited about those a

400
00:20:37,089 --> 00:20:42,528
meteorologist is excited about those a

401
00:20:39,880 --> 00:20:46,039
dynamicists and orbit celestial

402
00:20:42,528 --> 00:20:48,470
mechanics enthusiast is excited about

403
00:20:46,038 --> 00:20:49,579
those and so we're I'm gonna say I'm

404
00:20:48,470 --> 00:20:52,429
gonna step you through these big

405
00:20:49,579 --> 00:20:55,009
discoveries because like I said they

406
00:20:52,429 --> 00:20:59,778
fundamentally changed our view of Saturn

407
00:20:55,009 --> 00:21:02,419
of our solar system and of other solar

408
00:20:59,778 --> 00:21:08,898
systems and I don't know why my slides

409
00:21:02,419 --> 00:21:11,149
keep jumping around so I'm gonna set the

410
00:21:08,898 --> 00:21:14,418
context a little bit for you guys

411
00:21:11,148 --> 00:21:17,569
show you the Saturn system so this of

412
00:21:14,419 --> 00:21:20,570
course is Saturn the big planet here

413
00:21:17,569 --> 00:21:22,129
these are the rings you have the the

414
00:21:20,569 --> 00:21:27,099
classical rings those are the things

415
00:21:22,130 --> 00:21:30,889
Galileo saw big icy bright pretty rings

416
00:21:27,099 --> 00:21:33,528
but those continue outwards as we skip

417
00:21:30,888 --> 00:21:34,278
through some of the moons and there's an

418
00:21:33,528 --> 00:21:37,538
arrow here

419
00:21:34,278 --> 00:21:39,589
lots and lots more moons out this way

420
00:21:37,538 --> 00:21:42,769
including the biggest moon of the Saturn

421
00:21:39,589 --> 00:21:44,859
system Titan how many Titan fans are out

422
00:21:42,769 --> 00:21:48,038
there

423
00:21:44,859 --> 00:21:50,079
I hear there's some some theories about

424
00:21:48,038 --> 00:21:50,740
Titan so I got to follow up with you

425
00:21:50,079 --> 00:21:54,028
guys tonight

426
00:21:50,740 --> 00:21:56,649
about about new ideas about Titan okay

427
00:21:54,028 --> 00:22:00,970
we have that big pretty planet it's

428

00:21:56,648 --> 00:22:02,349
mostly hydrogen helium similar to to

429
00:22:00,970 --> 00:22:04,750
Jupiter some more similar to Jupiter

430
00:22:02,349 --> 00:22:06,849
than it is to Uranus and Neptune but as

431
00:22:04,750 --> 00:22:10,000
I'll show Saturn tells us a lot about

432
00:22:06,849 --> 00:22:12,069
all of the giant planets like I said

433
00:22:10,000 --> 00:22:14,048
those broad dense readings and the big

434
00:22:12,069 --> 00:22:17,500
dusty rings and in between there's a

435
00:22:14,048 --> 00:22:19,619
bunch of gaps those gaps actually tell

436
00:22:17,500 --> 00:22:22,329
us a whole lot about other solar systems

437
00:22:19,619 --> 00:22:25,209
so I'll step you through that and

438
00:22:22,329 --> 00:22:28,000
finally all of these cool moons so many

439
00:22:25,210 --> 00:22:30,909
moons okay

440
00:22:28,000 --> 00:22:33,460
let's start out with basically the

441
00:22:30,909 --> 00:22:35,380
atmosphere the storms that happen the

442
00:22:33,460 --> 00:22:36,720

weather that happens on Saturn and what

443

00:22:35,380 --> 00:22:41,169

we've learned with the Cassini mission

444

00:22:36,720 --> 00:22:43,419

so it's changed our view of Saturn we

445

00:22:41,169 --> 00:22:46,600

got there and we knew the atmosphere was

446

00:22:43,419 --> 00:22:49,840

gonna be interesting but from distance

447

00:22:46,599 --> 00:22:51,939

it's not as dynamic looking as what

448

00:22:49,839 --> 00:22:54,189

jupiter has cooper has those big

449

00:22:51,940 --> 00:22:57,308

exciting bands it has the Great Red Spot

450

00:22:54,190 --> 00:23:00,090

this giant hurricane it's lasted for

451

00:22:57,308 --> 00:23:02,288

years and years and years for centuries

452

00:23:00,089 --> 00:23:05,230

we didn't think Saturn was gonna be that

453

00:23:02,288 --> 00:23:07,329

interesting we were wrong scientists

454

00:23:05,230 --> 00:23:09,610

love being wrong it's changed our view

455

00:23:07,329 --> 00:23:11,230

of our solar system because there's

456

00:23:09,609 --> 00:23:13,359

other giant planets as I mentioned

457
00:23:11,230 --> 00:23:15,308
there's Jupiter Saturn Uranus and

458
00:23:13,359 --> 00:23:18,479
Neptune in our in our solar system and

459
00:23:15,308 --> 00:23:21,428
those also have these really complex

460
00:23:18,480 --> 00:23:23,798
atmospheres that we can now tie what

461
00:23:21,429 --> 00:23:25,389
we've learned at Saturn too and finally

462
00:23:23,798 --> 00:23:28,480
it's changed our view of other solar

463
00:23:25,388 --> 00:23:31,928
systems so over the course of Saturn's

464
00:23:28,480 --> 00:23:35,909
are of Cassini's lifetime we have seen

465
00:23:31,929 --> 00:23:38,470
there's a lot of exoplanets out there

466
00:23:35,909 --> 00:23:41,080
you guys throw a little timeline later

467
00:23:38,470 --> 00:23:43,839
but when Cassini launched we only knew

468
00:23:41,079 --> 00:23:46,689
of five other exoplanets five planets

469
00:23:43,839 --> 00:23:50,678
around other stars other worlds beyond

470
00:23:46,690 --> 00:23:55,149
our solar system five one handful and

471
00:23:50,679 --> 00:23:56,798
now we know a thousands so learning

472
00:23:55,148 --> 00:23:58,659
about the types of planets we're seeing

473
00:23:56,798 --> 00:24:01,049
elsewhere is so important

474
00:23:58,660 --> 00:24:04,630
and Cassini helps us study that so let's

475
00:24:01,049 --> 00:24:07,659
dive into the atmosphere here and this

476
00:24:04,630 --> 00:24:11,590
is probably the most iconic of the

477
00:24:07,660 --> 00:24:14,080
Saturn as a planet images this is known

478
00:24:11,589 --> 00:24:17,859
as the hexagon and I'm not talking about

479
00:24:14,079 --> 00:24:19,059
France I'm talking about this amazing

480
00:24:17,859 --> 00:24:23,469
structure here if you notice it's

481
00:24:19,059 --> 00:24:27,700
six-sided one two three four five and

482
00:24:23,470 --> 00:24:28,150
six it's a ball it's in the this is the

483
00:24:27,700 --> 00:24:29,920
North Pole

484
00:24:28,150 --> 00:24:34,150
right here so this is looking straight

485

00:24:29,920 --> 00:24:36,100
down onto Saturn and you can see in this

486
00:24:34,150 --> 00:24:39,580
this this false-color or

487
00:24:36,099 --> 00:24:40,899
representational color image that

488
00:24:39,579 --> 00:24:42,250
there's a whole bunch of structure here

489
00:24:40,900 --> 00:24:46,420
in the atmosphere these are all

490
00:24:42,250 --> 00:24:52,000
different storms knots of different wind

491
00:24:46,420 --> 00:24:56,170
patterns and density clusters inside the

492
00:24:52,000 --> 00:24:57,759
atmosphere and you can think of that

493
00:24:56,170 --> 00:24:59,740
this looks strange we thought we had

494
00:24:57,759 --> 00:25:03,190
seen it with other means other

495
00:24:59,740 --> 00:25:05,620
observations both ground-based and and a

496
00:25:03,190 --> 00:25:06,970
Voyager flyby we thought we'd seen this

497
00:25:05,619 --> 00:25:09,969
hexagonal structure but we weren't

498
00:25:06,970 --> 00:25:12,519
really sure and it didn't quite click we

499
00:25:09,970 --> 00:25:16,329

weren't sure why this would exist and if

500

00:25:12,519 --> 00:25:19,750

it could exist for decades but now we

501

00:25:16,329 --> 00:25:21,339

know it's there we confirmed it and one

502

00:25:19,750 --> 00:25:23,799

of the cool things about the Cassini

503

00:25:21,339 --> 00:25:25,809

mission is it has several instruments

504

00:25:23,799 --> 00:25:27,659

and each one of those instruments looks

505

00:25:25,809 --> 00:25:29,470

at a different wavelength of light

506

00:25:27,660 --> 00:25:33,210

basically a different color of light

507

00:25:29,470 --> 00:25:35,620

some of which our eyes can't see and

508

00:25:33,210 --> 00:25:38,559

some of those colors help us look

509

00:25:35,619 --> 00:25:42,489

through things so this is this is

510

00:25:38,559 --> 00:25:45,940

actually an infrared image it looks down

511

00:25:42,490 --> 00:25:49,960

into the layers of Saturn's upper

512

00:25:45,940 --> 00:25:54,670

atmosphere and we can then see that the

513

00:25:49,960 --> 00:26:01,630

thing that makes this this hexagon this

514
00:25:54,670 --> 00:26:05,259
pattern of airflow is a jet stream

515
00:26:01,630 --> 00:26:07,360
there's a jet stream at a lower level of

516
00:26:05,259 --> 00:26:10,349
the atmosphere that is causing this

517
00:26:07,359 --> 00:26:11,788
pattern to be set up

518
00:26:10,349 --> 00:26:14,399
this is actually kind of like a standing

519
00:26:11,788 --> 00:26:16,379
wave if you've ever had a rope with a

520
00:26:14,400 --> 00:26:18,120
have another friend hold the other side

521
00:26:16,380 --> 00:26:20,429
of the rope like a jump rope or had it

522
00:26:18,119 --> 00:26:22,500
connected to a wall and eventually you

523
00:26:20,429 --> 00:26:25,980
can just get to go up and down up and

524
00:26:22,500 --> 00:26:28,048
down so instead of just doing this the

525
00:26:25,980 --> 00:26:30,029
Rope just goes up down up down up down

526
00:26:28,048 --> 00:26:31,740
that's a standing wave the pattern

527
00:26:30,029 --> 00:26:32,519
actually really doesn't change this is a

528
00:26:31,740 --> 00:26:37,370
standing wave

529
00:26:32,519 --> 00:26:40,519
except it's huge and it's six sided and

530
00:26:37,369 --> 00:26:44,788
it's really interesting and also

531
00:26:40,519 --> 00:26:46,650
coincidentally beautiful really cool so

532
00:26:44,788 --> 00:26:48,329
we learn lots of lots about what's going

533
00:26:46,650 --> 00:26:51,200
on with the interior structure of Saturn

534
00:26:48,329 --> 00:26:55,859
this way oh and if you look closely

535
00:26:51,200 --> 00:26:58,429
you'll see this hard right in the very

536
00:26:55,859 --> 00:27:02,819
center right at the North Pole this is

537
00:26:58,429 --> 00:27:05,390
what's been called the Rose because it

538
00:27:02,819 --> 00:27:08,519
was cleverly colored in red in this

539
00:27:05,390 --> 00:27:10,980
representation or color image and it

540
00:27:08,519 --> 00:27:13,859
does look like a beautiful rose this is

541
00:27:10,980 --> 00:27:17,009
a giant hurricane right at the North

542

00:27:13,859 --> 00:27:20,359
Pole and this has told us a lot about

543
00:27:17,009 --> 00:27:23,009
how giant planet atmospheres might work

544
00:27:20,359 --> 00:27:24,569
because we're not just again remember I

545
00:27:23,009 --> 00:27:26,279
said that different wavelengths of light

546
00:27:24,569 --> 00:27:28,558
could probe different levels of

547
00:27:26,279 --> 00:27:31,558
atmosphere that means we can see

548
00:27:28,558 --> 00:27:34,798
vertical structures being able to see

549
00:27:31,558 --> 00:27:37,139
how tall a storm is is really important

550
00:27:34,798 --> 00:27:40,079
to understanding how it forms how it

551
00:27:37,140 --> 00:27:42,150
works the dynamics of it um have you

552
00:27:40,079 --> 00:27:43,980
guys ever been out on a summer day and

553
00:27:42,150 --> 00:27:47,090
you see a thunderstorm forming in the

554
00:27:43,980 --> 00:27:50,038
distance and you see that the clouds

555
00:27:47,089 --> 00:27:55,259
billow up and it forms kind of an anvil

556
00:27:50,038 --> 00:27:57,179

shape you and then you say oh I better

557

00:27:55,259 --> 00:27:58,950

get inside or I better drive home from

558

00:27:57,179 --> 00:28:00,840

work right now because that's gonna be a

559

00:27:58,950 --> 00:28:01,919

huge thunderstorm and I know what's

560

00:28:00,839 --> 00:28:03,740

gonna rain and I know there's gonna be

561

00:28:01,919 --> 00:28:05,909

Sun during lightning I better get home

562

00:28:03,740 --> 00:28:08,130

that's the same kind of thing that we're

563

00:28:05,909 --> 00:28:09,990

learning about here those verticals that

564

00:28:08,130 --> 00:28:15,809

vertical structure is really important

565

00:28:09,990 --> 00:28:18,298

to informing us how this works another

566

00:28:15,808 --> 00:28:22,889

example of the amazing storms we've seen

567

00:28:18,298 --> 00:28:24,009

on Saturn is this guy right here - see

568

00:28:22,890 --> 00:28:27,700

it's starting to form over here this

569

00:28:24,009 --> 00:28:30,579

regular quiet Saturn nothing too

570

00:28:27,700 --> 00:28:32,140

exciting happening like I mentioned

571
00:28:30,579 --> 00:28:35,589
before you know no no huge bands

572
00:28:32,140 --> 00:28:38,050
typically an in regular visible light

573
00:28:35,589 --> 00:28:40,659
Saturn looks kind of yellow kind of

574
00:28:38,049 --> 00:28:45,789
orange nothing big and bold happening

575
00:28:40,660 --> 00:28:49,509
and then we see a storm form and slowly

576
00:28:45,789 --> 00:28:52,230
that storm creates awake as different

577
00:28:49,509 --> 00:28:54,940
layers of the atmosphere move around it

578
00:28:52,230 --> 00:28:58,450
and you can see this time series where

579
00:28:54,940 --> 00:29:01,570
then it keeps going along into a long

580
00:28:58,450 --> 00:29:03,850
band and it wraps itself all the way

581
00:29:01,569 --> 00:29:09,549
around Saturn and eventually you have a

582
00:29:03,849 --> 00:29:11,079
very interesting curly fringed band so

583
00:29:09,549 --> 00:29:12,730
that's telling us how we've learned a

584
00:29:11,079 --> 00:29:16,929
lot does this happened over the course

585
00:29:12,730 --> 00:29:20,769
of several months and this thing lasted

586
00:29:16,930 --> 00:29:22,660
a couple years I think and so through

587
00:29:20,769 --> 00:29:28,000
this we were able to really learn about

588
00:29:22,660 --> 00:29:30,610
how storms form how they persist what

589
00:29:28,000 --> 00:29:31,630
may be causing them to to die out and

590
00:29:30,609 --> 00:29:33,279
quiet down

591
00:29:31,630 --> 00:29:34,900
so this also tells us about stuff on our

592
00:29:33,279 --> 00:29:37,259
own planet right we know about

593
00:29:34,900 --> 00:29:40,810
hurricanes hurricanes exist on earth and

594
00:29:37,259 --> 00:29:43,210
when you're over the ocean especially

595
00:29:40,809 --> 00:29:45,339
when it's warm you have the the moisture

596
00:29:43,210 --> 00:29:47,140
you have the heat that hurricane can

597
00:29:45,339 --> 00:29:49,720
build up and build up and build up and

598
00:29:47,140 --> 00:29:51,880
get really strong but the second it hits

599

00:29:49,720 --> 00:29:54,490
land you lose the moisture and it may

600
00:29:51,880 --> 00:29:56,830
die out the second it hits goes too far

601
00:29:54,490 --> 00:30:00,910
north and it hits some cold water it may

602
00:29:56,829 --> 00:30:04,210
die out so what a storm that persist is

603
00:30:00,910 --> 00:30:07,450
telling us is what's going on underneath

604
00:30:04,210 --> 00:30:10,390
what is giving the storm its power what

605
00:30:07,450 --> 00:30:12,640
is driving that storm so learning about

606
00:30:10,390 --> 00:30:15,670
how these work on Saturn really tells us

607
00:30:12,640 --> 00:30:20,620
a lot about how these work elsewhere for

608
00:30:15,670 --> 00:30:23,130
example Jupiter so toward the end of the

609
00:30:20,619 --> 00:30:27,669
Cassini mission we have the fantastic

610
00:30:23,130 --> 00:30:29,740
sibling the sibling spacecraft that goes

611
00:30:27,670 --> 00:30:34,450
out to Jupiter called the Juno mission

612
00:30:29,740 --> 00:30:36,558
and Juno mission has Juno cam which is

613
00:30:34,450 --> 00:30:38,840

actually a public outreach in

614

00:30:36,558 --> 00:30:40,460

it was not intended for science but

615

00:30:38,839 --> 00:30:41,928

we're seeing some amazing images come

616

00:30:40,460 --> 00:30:44,028

back from it that we're doing some

617

00:30:41,929 --> 00:30:46,909

science with you can compare this sort

618

00:30:44,028 --> 00:30:48,319

of storm on Jupiter you can see some

619

00:30:46,909 --> 00:30:50,120

vertical structure there are some other

620

00:30:48,319 --> 00:30:53,450

interesting things to what we seen on

621

00:30:50,119 --> 00:30:58,819

Saturn or you can look at things like

622

00:30:53,450 --> 00:31:01,220

this this is Neptune every image I can

623

00:30:58,819 --> 00:31:03,589

see in the first like three pages of a

624

00:31:01,220 --> 00:31:06,950

Google search on Neptune images is this

625

00:31:03,589 --> 00:31:09,678

image or some version of it it has this

626

00:31:06,950 --> 00:31:11,240

big storm here and I know Frank's talked

627

00:31:09,679 --> 00:31:12,440

about this storm before I think Anna

628
00:31:11,240 --> 00:31:14,480
news from the universe or something

629
00:31:12,440 --> 00:31:16,249
before at a public lecture series that

630
00:31:14,480 --> 00:31:19,220
storm doesn't exist anymore

631
00:31:16,249 --> 00:31:21,350
it hasn't existed for years and we know

632
00:31:19,220 --> 00:31:23,808
this but this is such an interesting

633
00:31:21,349 --> 00:31:26,118
image that this is the Neptune image

634
00:31:23,808 --> 00:31:28,428
that everybody associates with it

635
00:31:26,118 --> 00:31:32,808
this storm probably only lasted a few

636
00:31:28,429 --> 00:31:35,149
years but Neptune is different then say

637
00:31:32,808 --> 00:31:37,190
Jupiter Neptune is farther out from the

638
00:31:35,148 --> 00:31:39,908
Sun so it's cooler it's made of

639
00:31:37,190 --> 00:31:42,470
different stuff like there's ammonia and

640
00:31:39,909 --> 00:31:46,100
some other like not it's not hydrogen

641
00:31:42,470 --> 00:31:47,329
helium like like Jupiter and Saturn lots

642
00:31:46,099 --> 00:31:51,498
of other things going on in the

643
00:31:47,329 --> 00:31:53,329
atmosphere so what we're learning is by

644
00:31:51,499 --> 00:31:54,470
looking at just the four examples in our

645
00:31:53,329 --> 00:31:57,558
solar system

646
00:31:54,470 --> 00:32:01,038
how much fears are different there's no

647
00:31:57,558 --> 00:32:03,408
cookie cutter formula for how these

648
00:32:01,038 --> 00:32:05,929
things work and now that we have

649
00:32:03,409 --> 00:32:08,299
thousands of candidates of exoplanets

650
00:32:05,929 --> 00:32:10,909
many of which are gas giants of some

651
00:32:08,298 --> 00:32:13,038
sort we can now start to put the pieces

652
00:32:10,909 --> 00:32:17,600
together and learn more about how these

653
00:32:13,038 --> 00:32:22,548
things work and not expect as scientists

654
00:32:17,599 --> 00:32:25,519
who model these things can't expect them

655
00:32:22,548 --> 00:32:27,319
all to work the same way especially when

656

00:32:25,519 --> 00:32:29,450
they're in different circumstances say

657
00:32:27,319 --> 00:32:30,859
you have a gas giant that's off that's a

658
00:32:29,450 --> 00:32:33,649
hot Jupiter who's here heard of a hot

659
00:32:30,859 --> 00:32:36,229
Jupiter that's something roughly Jupiter

660
00:32:33,648 --> 00:32:40,599
sized that's really close into the star

661
00:32:36,230 --> 00:32:44,329
closer than mercury is to our Sun so

662
00:32:40,599 --> 00:32:45,618
it's really hot right they're so hot in

663
00:32:44,329 --> 00:32:47,928
fact that you know the the atmosphere

664
00:32:45,618 --> 00:32:49,329
could bubble away could evaporate away

665
00:32:47,929 --> 00:32:51,490
from the heat of the Sun

666
00:32:49,329 --> 00:32:52,779
um it's so close that it's tidally

667
00:32:51,490 --> 00:32:54,279
locked that means there's one side

668
00:32:52,779 --> 00:32:59,680
that's always daytime one side that's

669
00:32:54,279 --> 00:33:01,389
always nighttime it could it could be

670
00:32:59,680 --> 00:33:03,160

really far far far far far far away

671

00:33:01,390 --> 00:33:06,910

and be very very cold but still really

672

00:33:03,160 --> 00:33:08,740

big what happens there we we need to

673

00:33:06,910 --> 00:33:10,900

answer cities and so studying saying

674

00:33:08,740 --> 00:33:12,700

that what I call our backyard Laboratory

675

00:33:10,900 --> 00:33:15,400

versus that solar system is really

676

00:33:12,700 --> 00:33:18,190

important because now we have all these

677

00:33:15,400 --> 00:33:19,960

candidates we want to know what's going

678

00:33:18,190 --> 00:33:21,460

on with them we want to know how these

679

00:33:19,960 --> 00:33:24,789

work we also are finding out

680

00:33:21,460 --> 00:33:26,529

compositional information every day the

681

00:33:24,789 --> 00:33:28,869

Webb telescope is going to tell us what

682

00:33:26,529 --> 00:33:31,779

these atmospheres are made of and we

683

00:33:28,869 --> 00:33:33,279

need what we call ground truth the

684

00:33:31,779 --> 00:33:36,759

Cassini mission has given us some ground

685
00:33:33,279 --> 00:33:39,730
truth some some really concrete evidence

686
00:33:36,759 --> 00:33:44,160
nearby of something that we know of that

687
00:33:39,730 --> 00:33:48,160
we have observed for a long time and we

688
00:33:44,160 --> 00:33:50,110
we can compare to I turn them all use

689
00:33:48,160 --> 00:33:53,230
later and throughout this talk is

690
00:33:50,109 --> 00:33:55,149
comparative planetology so that's really

691
00:33:53,230 --> 00:33:58,049
important for what we're doing and what

692
00:33:55,150 --> 00:34:00,460
the Cassini mission has contributed okay

693
00:33:58,049 --> 00:34:02,019
Owen the planetary wings

694
00:34:00,460 --> 00:34:03,549
you saw that I talked a lot about

695
00:34:02,019 --> 00:34:05,740
atmospheres wait till you get me started

696
00:34:03,549 --> 00:34:07,990
on the planetary rings I love planetary

697
00:34:05,740 --> 00:34:13,690
rings that's my background I'm all about

698
00:34:07,990 --> 00:34:14,980
the Rings so for Saturn itself we

699
00:34:13,690 --> 00:34:17,170
weren't really sure about the Rings when

700
00:34:14,980 --> 00:34:20,710
we got there we've seen some cool stuff

701
00:34:17,170 --> 00:34:23,530
with Voyager we've seen some cool stuff

702
00:34:20,710 --> 00:34:26,349
from the ground but we weren't really

703
00:34:23,530 --> 00:34:28,690
sure what we've learned is the ring

704
00:34:26,349 --> 00:34:31,869
rings are ancient they've probably

705
00:34:28,690 --> 00:34:34,269
formed with Saturn they're massive

706
00:34:31,869 --> 00:34:36,489
they're probably you know a fractional

707
00:34:34,269 --> 00:34:39,159
size of a moon which is way bigger than

708
00:34:36,489 --> 00:34:41,619
we thought they were going to be they

709
00:34:39,159 --> 00:34:44,679
have all kinds of complex structures

710
00:34:41,619 --> 00:34:48,730
inside including small moons that we

711
00:34:44,679 --> 00:34:51,179
call moonlets they have the change on

712
00:34:48,730 --> 00:34:53,769
small timescales human timescales

713

00:34:51,179 --> 00:34:57,339
Cassini life time schedules which is

714
00:34:53,769 --> 00:34:58,659
unheard of for astronomical objects you

715
00:34:57,340 --> 00:35:00,789
know we're not dealing with millions and

716
00:34:58,659 --> 00:35:03,039
billions of years for a change we're

717
00:35:00,789 --> 00:35:05,679
talking about weeks

718
00:35:03,039 --> 00:35:07,150
months I once did a paper where I

719
00:35:05,679 --> 00:35:13,419
measured how things changed over the

720
00:35:07,150 --> 00:35:15,430
course of 28 days what you know you know

721
00:35:13,420 --> 00:35:17,889
the grass and my the the grass in my

722
00:35:15,429 --> 00:35:21,210
yard at home grows on the same time

723
00:35:17,889 --> 00:35:23,650
scales that some of these things happen

724
00:35:21,210 --> 00:35:27,460
thank goodness I don't have to mow the

725
00:35:23,650 --> 00:35:31,269
Rings okay it also changed our view of

726
00:35:27,460 --> 00:35:34,389
our solar system Ksenia our Saturn is

727
00:35:31,269 --> 00:35:37,269

not the only planet with rings Jupiter

728

00:35:34,389 --> 00:35:40,329

Uranus and Neptune also have rings

729

00:35:37,269 --> 00:35:41,829

they're different but now we know the

730

00:35:40,329 --> 00:35:44,769

ring systems are not necessarily

731

00:35:41,829 --> 00:35:46,719

temporary this makes sense because we

732

00:35:44,769 --> 00:35:49,000

see them around all four of the large

733

00:35:46,719 --> 00:35:53,159

planets in our solar system so it clicks

734

00:35:49,000 --> 00:35:55,780

and these rings are constantly evolving

735

00:35:53,159 --> 00:35:57,969

again helping us piece together the

736

00:35:55,780 --> 00:35:59,290

puzzles for these rings especially on

737

00:35:57,969 --> 00:36:01,869

Uranus and Neptune that we haven't

738

00:35:59,289 --> 00:36:04,329

gotten a really good look at we've only

739

00:36:01,869 --> 00:36:07,000

gotten some some Voyager data back from

740

00:36:04,329 --> 00:36:09,369

them so we really want to know more and

741

00:36:07,000 --> 00:36:11,559

finally told us about other solar

742
00:36:09,369 --> 00:36:13,509
systems so I'm not talking about the

743
00:36:11,559 --> 00:36:15,909
ring systems in other solar system I'm

744
00:36:13,510 --> 00:36:18,850
talking about the disks that surround

745
00:36:15,909 --> 00:36:21,879
those other Suns that planets are born

746
00:36:18,849 --> 00:36:26,500
from the rings are an excellent example

747
00:36:21,880 --> 00:36:29,340
of an Astrophysical disc and another

748
00:36:26,500 --> 00:36:33,460
example of an Astrophysical disc is a

749
00:36:29,340 --> 00:36:37,300
protoplanetary disc the the gas and dust

750
00:36:33,460 --> 00:36:40,000
and debris that forms new planets and by

751
00:36:37,300 --> 00:36:42,789
looking at Saturn and the Rings and how

752
00:36:40,000 --> 00:36:48,039
moons form in those rings we can learn

753
00:36:42,789 --> 00:36:51,779
about how complex worlds are built in

754
00:36:48,039 --> 00:36:55,690
the debris disks around new stars okay

755
00:36:51,780 --> 00:36:59,950
let's set the context again broad dense

756
00:36:55,690 --> 00:37:02,829
rings the classical rings ABC the gaps

757
00:36:59,949 --> 00:37:05,439
within those classical rings and then

758
00:37:02,829 --> 00:37:07,759
this huge dusty component which

759
00:37:05,440 --> 00:37:14,059
encompasses the E

760
00:37:07,760 --> 00:37:16,250
jee-in the Phoebe ring alright and what

761
00:37:14,059 --> 00:37:19,400
are Saturn's rings made of they are made

762
00:37:16,250 --> 00:37:21,829
of water ice so for those of you from

763
00:37:19,400 --> 00:37:24,380
Philadelphia I apologize it's not some

764
00:37:21,829 --> 00:37:28,809
delicious treat when I say water ice I'm

765
00:37:24,380 --> 00:37:33,619
talking about h2o so this is actual ice

766
00:37:28,809 --> 00:37:36,559
that is in all kinds of sizes so it's

767
00:37:33,619 --> 00:37:39,440
huge distribution from from dust sized

768
00:37:36,559 --> 00:37:43,630
grains of ice all the way up to things

769
00:37:39,440 --> 00:37:46,480
the size of cars and houses we have

770

00:37:43,630 --> 00:37:49,099
these things are constantly moving

771
00:37:46,480 --> 00:37:50,809
smashing into each other sticking and

772
00:37:49,099 --> 00:37:53,089
then those things are hitting each other

773
00:37:50,809 --> 00:37:57,199
and pulling each other apart this is a

774
00:37:53,090 --> 00:37:59,329
constant swirl of activity and what the

775
00:37:57,199 --> 00:38:02,199
Cassini mission has really shown us is

776
00:37:59,329 --> 00:38:05,360
how dynamic these rings are that this

777
00:38:02,199 --> 00:38:09,730
process of smashing and accretion and

778
00:38:05,360 --> 00:38:12,650
destruction is constantly happening

779
00:38:09,730 --> 00:38:15,050
okay so what we're really learning is

780
00:38:12,650 --> 00:38:18,260
that the Saturn system is not a ring

781
00:38:15,050 --> 00:38:20,630
system it is a ring moon system and

782
00:38:18,260 --> 00:38:22,790
these rings and moons are constantly

783
00:38:20,630 --> 00:38:28,130
doing a dance

784
00:38:22,789 --> 00:38:29,869

there are 62 named moons but I like to

785

00:38:28,130 --> 00:38:32,329

say that there are billions and billions

786

00:38:29,869 --> 00:38:34,789

of moons at Saturn because each one of

787

00:38:32,329 --> 00:38:37,130

those little particles in the Rings is a

788

00:38:34,789 --> 00:38:40,070

moon they're all orbiting Saturn

789

00:38:37,130 --> 00:38:43,010

together in this beautiful dance so

790

00:38:40,070 --> 00:38:49,070

let's zoom in into the outer be ring

791

00:38:43,010 --> 00:38:51,700

edge and we see vertical structure the

792

00:38:49,070 --> 00:38:54,940

Cassini mission was there for equinox

793

00:38:51,699 --> 00:39:00,889

equinoxes when the tilt of the Rings

794

00:38:54,940 --> 00:39:03,139

perfectly lines up with the the plane of

795

00:39:00,889 --> 00:39:07,909

our solar system so that the Sun is

796

00:39:03,139 --> 00:39:10,400

perfectly on edge and there's no so that

797

00:39:07,909 --> 00:39:13,549

means that it casts shadows anything

798

00:39:10,400 --> 00:39:16,940

sticking up from that flat plane of the

799

00:39:13,550 --> 00:39:18,680

Rings is going to cast a shadow this

800

00:39:16,940 --> 00:39:22,210

really helped us because we saw at the

801

00:39:18,679 --> 00:39:26,049

outer edge of the B ring we saw man

802

00:39:22,210 --> 00:39:29,650

these are all mountains and it's not an

803

00:39:26,050 --> 00:39:32,340

even distribution it's really really

804

00:39:29,650 --> 00:39:35,079

kind of a funky look in no symmetry

805

00:39:32,340 --> 00:39:39,039

these are I said these are mountains

806

00:39:35,079 --> 00:39:41,380

these are thousands of feet tall and we

807

00:39:39,039 --> 00:39:44,949

see those those those cool shadows

808

00:39:41,380 --> 00:39:47,440

coming out from them so we know what how

809

00:39:44,949 --> 00:39:49,929

tall they actually are so then it comes

810

00:39:47,440 --> 00:39:52,840

down to the dynamicists and we

811

00:39:49,929 --> 00:39:55,569

dynamicists looked at this and we've

812

00:39:52,840 --> 00:39:56,980

tracked out where other moons were we

813
00:39:55,570 --> 00:40:01,600
tried to figure out what was causing

814
00:39:56,980 --> 00:40:04,809
this and we said that's no moon well

815
00:40:01,599 --> 00:40:08,019
actually it is it's called - or Mimas

816
00:40:04,809 --> 00:40:09,670
people say it both ways and this is a

817
00:40:08,019 --> 00:40:11,829
moon that's just outside of the

818
00:40:09,670 --> 00:40:16,240
classical rings that's where its orbit

819
00:40:11,829 --> 00:40:18,250
is and it picks on the ring particles it

820
00:40:16,239 --> 00:40:22,000
tugs on them just a little bit with its

821
00:40:18,250 --> 00:40:24,219
gravity tug tug tug and just like you

822
00:40:22,000 --> 00:40:25,630
might have a tub of water and when you

823
00:40:24,219 --> 00:40:28,839
move it back and forth it actually

824
00:40:25,630 --> 00:40:31,690
sloshes so that stuff comes up the waves

825
00:40:28,840 --> 00:40:34,180
come up out of the tub that's what's

826
00:40:31,690 --> 00:40:37,720
happening here so we have vertical

827

00:40:34,179 --> 00:40:41,079
structure because of the sloshing that -

828
00:40:37,719 --> 00:40:42,549
causes so this causes vertical but if

829
00:40:41,079 --> 00:40:44,139
you were to look down on a vertical

830
00:40:42,550 --> 00:40:46,390
you'd really just see a density

831
00:40:44,139 --> 00:40:50,079
enhancement so you'd see a big clump of

832
00:40:46,389 --> 00:40:52,089
stuff it's very thick there and when we

833
00:40:50,079 --> 00:40:53,889
look at other solar systems other

834
00:40:52,090 --> 00:40:57,519
forming solar system we see a disc

835
00:40:53,889 --> 00:40:59,710
around a star so this is where that star

836
00:40:57,519 --> 00:41:02,050
would be this is the whole disc and you

837
00:40:59,710 --> 00:41:05,889
can see that's not a pretty uniform disc

838
00:41:02,050 --> 00:41:09,400
there are bright spots here kind of over

839
00:41:05,889 --> 00:41:11,799
here and empty spots up here that looks

840
00:41:09,400 --> 00:41:14,050
surprisingly like the kinds of weird

841
00:41:11,800 --> 00:41:16,080

structures we see at the B rings edge so

842

00:41:14,050 --> 00:41:18,960

a ring scientist sees that and says oh

843

00:41:16,079 --> 00:41:23,799

there's a planet there there's a planet

844

00:41:18,960 --> 00:41:27,369

so what we can learn from rings applies

845

00:41:23,800 --> 00:41:30,700

to protoplanetary discs - debris disks

846

00:41:27,369 --> 00:41:33,250

that sort of thing just for comparison

847

00:41:30,699 --> 00:41:34,460

this is this is really big this here

848

00:41:33,250 --> 00:41:36,800

would be

849

00:41:34,460 --> 00:41:40,220

Oh's orbit in our solar system so you

850

00:41:36,800 --> 00:41:43,220

can you can match how big this disk

851

00:41:40,219 --> 00:41:44,959

really is I mean the dynamicists can map

852

00:41:43,219 --> 00:41:48,259

that and figure out where to look for

853

00:41:44,960 --> 00:41:50,420

the planet in this system okay so let's

854

00:41:48,260 --> 00:41:54,020

go back to Saturn's rings for another

855

00:41:50,420 --> 00:41:56,690

example out to the Aerie the airing is

856
00:41:54,019 --> 00:41:58,190
where we see these gaps and we knew

857
00:41:56,690 --> 00:41:59,929
about this before Cassini we knew there

858
00:41:58,190 --> 00:42:02,480
were two gaps in the a ring

859
00:41:59,929 --> 00:42:05,929
there was the inky gap and the Keeler

860
00:42:02,480 --> 00:42:08,269
gap an inky gap was was big enough to

861
00:42:05,929 --> 00:42:12,199
really see pretty well the Keeler gap

862
00:42:08,269 --> 00:42:16,400
was very thin with the inky gap we saw a

863
00:42:12,199 --> 00:42:19,489
moon we call that pan and we saw it I

864
00:42:16,400 --> 00:42:21,230
mean we didn't know what Pam looked like

865
00:42:19,489 --> 00:42:26,118
till we got there but basically it's a

866
00:42:21,230 --> 00:42:29,000
sad twisted little potato you know maybe

867
00:42:26,119 --> 00:42:33,140
maybe the size of Manhattan Island

868
00:42:29,000 --> 00:42:35,030
something like that but we only saw the

869
00:42:33,139 --> 00:42:35,480
Keeler gap we didn't see anything inside

870
00:42:35,030 --> 00:42:38,930
of it

871
00:42:35,480 --> 00:42:42,260
so we thought well what else could

872
00:42:38,929 --> 00:42:45,980
cleared this whole gap there must be a

873
00:42:42,260 --> 00:42:50,119
moon there so Cassini looks for it and

874
00:42:45,980 --> 00:42:52,969
Cassini found it in this gap this Keeler

875
00:42:50,119 --> 00:42:55,190
gap that is only about 40 kilometers

876
00:42:52,969 --> 00:42:58,819
wide we were able to find it even

877
00:42:55,190 --> 00:43:02,838
smaller even sadder even more twisted

878
00:42:58,820 --> 00:43:06,530
and rotten potato and so we gave it the

879
00:43:02,838 --> 00:43:08,750
lovely name Daphna s-- and we learned

880
00:43:06,530 --> 00:43:12,560
something else because the Keeler gap is

881
00:43:08,750 --> 00:43:15,530
so small you can see Daphna spilling on

882
00:43:12,559 --> 00:43:20,150
the edges of it oh you could see it kind

883
00:43:15,530 --> 00:43:21,619
of here and this structure again it's

884

00:43:20,150 --> 00:43:24,050
the same kind of structure that happened

885
00:43:21,619 --> 00:43:25,700
in the outer B ring that vertical

886
00:43:24,050 --> 00:43:27,950
structure there's there's a wave or a

887
00:43:25,699 --> 00:43:29,989
wake kind of like if you think of a boat

888
00:43:27,949 --> 00:43:32,480
going through water or something very

889
00:43:29,989 --> 00:43:35,149
similar is happening there same kind of

890
00:43:32,480 --> 00:43:38,630
mechanics over in the width pan that it

891
00:43:35,150 --> 00:43:41,480
disturbs in the inky gap and so we know

892
00:43:38,630 --> 00:43:43,700
this is this kind of thing happens moons

893
00:43:41,480 --> 00:43:46,519
form within the Rings and they can clear

894
00:43:43,699 --> 00:43:48,259
large swaths of the Rings so again let's

895
00:43:46,519 --> 00:43:49,759
take that out to our gala

896
00:43:48,260 --> 00:43:52,280
see let's take that to other stars

897
00:43:49,760 --> 00:43:54,800
because we see debris disks everywhere

898
00:43:52,280 --> 00:43:59,019

and when we see a debris disc like we

899

00:43:54,800 --> 00:44:03,700

did here with Hubble we see a big gap

900

00:43:59,019 --> 00:44:07,489

around this particular star in its disk

901

00:44:03,699 --> 00:44:09,079

again a ring this person says oh there's

902

00:44:07,489 --> 00:44:12,439

a planet there there's a planet there I

903

00:44:09,079 --> 00:44:13,849

know it so you do something this is this

904

00:44:12,440 --> 00:44:17,329

an illustration of what could be

905

00:44:13,849 --> 00:44:20,029

happening here the same kind of ring

906

00:44:17,329 --> 00:44:24,289

exists so now we have we have a place to

907

00:44:20,030 --> 00:44:26,860

target our observations a mission like

908

00:44:24,289 --> 00:44:29,750

the like the James Webb Space Telescope

909

00:44:26,860 --> 00:44:32,079

will be able to do a good job of looking

910

00:44:29,750 --> 00:44:36,230

for a planet in there if it's big enough

911

00:44:32,079 --> 00:44:39,619

because the the dust and the gas and the

912

00:44:36,230 --> 00:44:41,869

debris disc will will the infrared light

913
00:44:39,619 --> 00:44:45,409
of the star may be able to pierce

914
00:44:41,869 --> 00:44:47,480
through it so at plus it has a

915
00:44:45,409 --> 00:44:49,699
coronagraph that'll block out the star

916
00:44:47,480 --> 00:44:50,740
so what we might be able to see it that

917
00:44:49,699 --> 00:44:53,889
way

918
00:44:50,739 --> 00:44:53,889
[Music]

919
00:44:54,130 --> 00:45:02,570
plus there's all kinds of other like I

920
00:44:58,820 --> 00:45:03,170
said before other systems in our solar

921
00:45:02,570 --> 00:45:07,250
system

922
00:45:03,170 --> 00:45:11,119
there's Uranus and Neptune here very

923
00:45:07,250 --> 00:45:13,489
thin very dark rings but they can teach

924
00:45:11,119 --> 00:45:16,400
us something as well and the lessons

925
00:45:13,489 --> 00:45:19,009
learned at Saturn with Cassini can be

926
00:45:16,400 --> 00:45:21,559
applied here to learn what's going on we

927
00:45:19,010 --> 00:45:24,740
think that there are moons being created

928
00:45:21,559 --> 00:45:29,989
in the ring system of Uranus we've seen

929
00:45:24,739 --> 00:45:33,109
rings change since Voyager in at Neptune

930
00:45:29,989 --> 00:45:35,329
so we know things are happening that

931
00:45:33,110 --> 00:45:37,579
these are dynamic rings as well so we're

932
00:45:35,329 --> 00:45:39,559
people who worked on the Cassini mission

933
00:45:37,579 --> 00:45:42,159
are now turning their attention to

934
00:45:39,559 --> 00:45:45,349
Uranus and Neptune especially using

935
00:45:42,159 --> 00:45:47,089
Hubble and putting in proposals for the

936
00:45:45,349 --> 00:45:51,309
James Webb Space Telescope to be able to

937
00:45:47,090 --> 00:45:54,019
study what's happening in those systems

938
00:45:51,309 --> 00:45:58,009
our solar system itself has two

939
00:45:54,019 --> 00:46:00,500
Astrophysical discs we have the asteroid

940
00:45:58,010 --> 00:46:02,740
belt which is here between Mars and

941

00:46:00,500 --> 00:46:02,739

Jupiter

942

00:46:03,449 --> 00:46:09,730

when we have the Kuiper belt which is

943

00:46:06,099 --> 00:46:12,969

out beyond the orbit of Neptune kind of

944

00:46:09,730 --> 00:46:16,420

where Pluto sets and both of those are

945

00:46:12,969 --> 00:46:18,849

remnants of our solar system of the

946

00:46:16,420 --> 00:46:21,430

formation of our solar system and by

947

00:46:18,849 --> 00:46:24,730

looking at those by studying those we

948

00:46:21,429 --> 00:46:28,119

can tell what happened in the formation

949

00:46:24,730 --> 00:46:30,309

of our solar system and learning about

950

00:46:28,119 --> 00:46:34,480

the dynamics of health of the Saturn

951

00:46:30,309 --> 00:46:37,509

system applying that to the our solar

952

00:46:34,480 --> 00:46:39,340

system and what it looks like now we can

953

00:46:37,510 --> 00:46:41,020

start to put the piece the puzzle pieces

954

00:46:39,340 --> 00:46:43,410

together

955

00:46:41,019 --> 00:46:45,460

for example there's an interesting

956

00:46:43,409 --> 00:46:48,190

dynamical thing that probably happened

957

00:46:45,460 --> 00:46:51,570

in the asteroid belt a resonance that is

958

00:46:48,190 --> 00:46:55,269

evidence that the four giant planets

959

00:46:51,570 --> 00:46:58,539

used to be closer in together and that

960

00:46:55,269 --> 00:47:00,190

they jiggled out separated and while

961

00:46:58,539 --> 00:47:04,029

they were doing that Uranus and Neptune

962

00:47:00,190 --> 00:47:05,349

probably swapped spots so tracing out

963

00:47:04,030 --> 00:47:07,810

the dynamics of these kinds of

964

00:47:05,349 --> 00:47:09,159

Astrophysical discs is really important

965

00:47:07,809 --> 00:47:12,730

for us understanding our own solar

966

00:47:09,159 --> 00:47:14,889

system and as I mentioned before we know

967

00:47:12,730 --> 00:47:17,769

of all these debris disks plant

968

00:47:14,889 --> 00:47:21,519

protoplanetary discs across our galaxy

969

00:47:17,769 --> 00:47:24,960

that we can apply lessons learned to to

970
00:47:21,519 --> 00:47:27,759
be able to learn how planets are forming

971
00:47:24,960 --> 00:47:30,039
target where to find them in the disk

972
00:47:27,760 --> 00:47:32,530
and we have all these new telescopes

973
00:47:30,039 --> 00:47:34,900
coming up including the James Webb where

974
00:47:32,530 --> 00:47:38,830
we'll be able to look into these dusty

975
00:47:34,900 --> 00:47:41,860
discs using infrared all right so really

976
00:47:38,829 --> 00:47:45,610
this and this is my bike mantra Saturn's

977
00:47:41,860 --> 00:47:47,380
rings are a natural lab we must go back

978
00:47:45,610 --> 00:47:49,840
we've learned so much already and we can

979
00:47:47,380 --> 00:47:54,940
learn more okay

980
00:47:49,840 --> 00:47:58,000
and finally the Third Point icy moons of

981
00:47:54,940 --> 00:48:02,769
the big discoveries so big the icy moons

982
00:47:58,000 --> 00:48:06,599
we knew about but we didn't know until

983
00:48:02,769 --> 00:48:09,460
we got there that Enceladus has plumes

984
00:48:06,599 --> 00:48:11,380
meaning geysers something like Old

985
00:48:09,460 --> 00:48:17,800
Faithful which we like to call cold

986
00:48:11,380 --> 00:48:22,690
Faithful by the way Titan has lakes this

987
00:48:17,800 --> 00:48:25,510
big earth-like moon has lakes liquid

988
00:48:22,690 --> 00:48:28,200
lakes we didn't know that before we got

989
00:48:25,510 --> 00:48:30,460
to Saturday before Cassini got to Saturn

990
00:48:28,199 --> 00:48:32,769
so then we changed our view of our solar

991
00:48:30,460 --> 00:48:35,320
system because we learnt we realized icy

992
00:48:32,769 --> 00:48:37,239
moons can be geologically active we

993
00:48:35,320 --> 00:48:40,710
didn't think that was possible we

994
00:48:37,239 --> 00:48:44,349
thought icy moons were just hunks of ice

995
00:48:40,710 --> 00:48:45,699
leftover from maybe the formation of the

996
00:48:44,349 --> 00:48:48,279
planet itself or maybe they were

997
00:48:45,699 --> 00:48:50,379
captured from the Kuiper belt or you

998

00:48:48,280 --> 00:48:53,620
know some some kind of lone comment that

999
00:48:50,380 --> 00:48:56,200
got trapped but no this is really

1000
00:48:53,619 --> 00:48:57,839
interesting and then when we applied to

1001
00:48:56,199 --> 00:49:03,159
other solar systems we realized

1002
00:48:57,840 --> 00:49:05,079
geologically active moons could Harbor

1003
00:49:03,159 --> 00:49:08,289
life they could be warm enough that

1004
00:49:05,079 --> 00:49:10,360
we're getting the right environmental

1005
00:49:08,289 --> 00:49:13,029
conditions for life to exist on them and

1006
00:49:10,360 --> 00:49:15,430
this expands our whole view of what

1007
00:49:13,030 --> 00:49:18,120
habitability means of what a habitable

1008
00:49:15,429 --> 00:49:21,579
world is expanding those definitions is

1009
00:49:18,119 --> 00:49:24,579
huge because astrobiology is a

1010
00:49:21,579 --> 00:49:26,079
burgeoning field even today and we're

1011
00:49:24,579 --> 00:49:28,630
learning new things every day which

1012
00:49:26,079 --> 00:49:31,869

Cassini has really helped point to so

1013

00:49:28,630 --> 00:49:35,410

again setting the context all kinds of

1014

00:49:31,869 --> 00:49:37,569

moons going out from the Rings even more

1015

00:49:35,409 --> 00:49:41,440

farther out that we don't have room for

1016

00:49:37,570 --> 00:49:44,550

on this screen but let's start with

1017

00:49:41,440 --> 00:49:49,840

Titan so Titan is the biggest moon of

1018

00:49:44,550 --> 00:49:52,539

Saturn system Titan at first glance and

1019

00:49:49,840 --> 00:49:55,150

visible lights just looks fuzzy and

1020

00:49:52,539 --> 00:50:00,099

orange that's because it has this big

1021

00:49:55,150 --> 00:50:02,950

thick atmosphere really big and thick as

1022

00:50:00,099 --> 00:50:06,309

a matter of fact in in one of the the

1023

00:50:02,949 --> 00:50:08,919

more recent Star Trek movies the the

1024

00:50:06,309 --> 00:50:11,650

enterprise hid inside of those that hazy

1025

00:50:08,920 --> 00:50:16,269

atmosphere because it's so good at

1026

00:50:11,650 --> 00:50:18,130

hiding things in visible wavelengths but

1027
00:50:16,269 --> 00:50:22,039
once you get inside

1028
00:50:18,130 --> 00:50:23,360
and look at it underneath those layers

1029
00:50:22,039 --> 00:50:26,539
with the instruments that were on

1030
00:50:23,360 --> 00:50:30,680
Cassini and with the lander that went

1031
00:50:26,539 --> 00:50:34,909
down called the Huygens probe we could

1032
00:50:30,679 --> 00:50:37,210
see the actual surface of Titan and we

1033
00:50:34,909 --> 00:50:41,359
were able to make out methane lakes

1034
00:50:37,210 --> 00:50:43,789
these if you look carefully you study

1035
00:50:41,360 --> 00:50:45,829
other close-up photos you realize that

1036
00:50:43,789 --> 00:50:49,090
there are shorelines

1037
00:50:45,829 --> 00:50:52,519
you realize that this is actually liquid

1038
00:50:49,090 --> 00:50:56,360
standing liquid and you check out the

1039
00:50:52,519 --> 00:51:00,440
chemistry of the moon and you see that

1040
00:50:56,360 --> 00:51:03,110
it's methane so just like our earth has

1041
00:51:00,440 --> 00:51:07,519
a water cycle where we have water on the

1042
00:51:03,110 --> 00:51:10,610
ground he gets heated up becomes clouds

1043
00:51:07,519 --> 00:51:12,860
rains back down seeps into the ground

1044
00:51:10,610 --> 00:51:16,670
and two aquifers and then comes back up

1045
00:51:12,860 --> 00:51:19,910
into lakes that kind of cycle Titan has

1046
00:51:16,670 --> 00:51:23,510
something similar but for methane what a

1047
00:51:19,909 --> 00:51:26,239
bizarre and cool world and as a result

1048
00:51:23,510 --> 00:51:29,510
it makes it the most earth-like thing in

1049
00:51:26,239 --> 00:51:36,439
our solar system besides Earth this is

1050
00:51:29,510 --> 00:51:39,440
fantastic but it's also very cold so I

1051
00:51:36,440 --> 00:51:41,030
don't know that it's the best candidate

1052
00:51:39,440 --> 00:51:44,679
for habitability but it is stretching

1053
00:51:41,030 --> 00:51:47,660
our thinking on what habitability is

1054
00:51:44,679 --> 00:51:50,210
even if it's cold it does have this

1055

00:51:47,659 --> 00:51:54,949
liquid liquid on the surface it has

1056
00:51:50,210 --> 00:51:57,829
lakes it has it has dunes it has sand

1057
00:51:54,949 --> 00:52:00,469
dunes now some of its it's tiny pieces

1058
00:51:57,829 --> 00:52:03,650
of ice rather than rocky you type of

1059
00:52:00,469 --> 00:52:06,679
sand that we have on earth but how it

1060
00:52:03,650 --> 00:52:11,360
has winds it has weather it rains

1061
00:52:06,679 --> 00:52:15,769
liquid methane again but this is really

1062
00:52:11,360 --> 00:52:20,120
fascinating so we have a complex world

1063
00:52:15,769 --> 00:52:23,000
here that we're looking at then a little

1064
00:52:20,119 --> 00:52:24,079
bit later in the mission I actually got

1065
00:52:23,000 --> 00:52:28,300
to be part of this one so I'm really

1066
00:52:24,079 --> 00:52:31,069
excited about this story we were working

1067
00:52:28,300 --> 00:52:33,860
with a team the team that does the

1068
00:52:31,070 --> 00:52:35,109
imaging of course the imaging team Rives

1069
00:52:33,860 --> 00:52:37,420

all the benefits

1070

00:52:35,108 --> 00:52:40,058
on Cassini the beautiful images

1071

00:52:37,420 --> 00:52:45,338
everybody loves the imaging science

1072

00:52:40,059 --> 00:52:47,559
subsystem but they see something around

1073

00:52:45,338 --> 00:52:48,278
and celibacy and they think that can't

1074

00:52:47,559 --> 00:52:49,959
be right

1075

00:52:48,278 --> 00:52:52,838
there's got to be something wrong with

1076

00:52:49,958 --> 00:52:55,088
the detector we had some kind of anomaly

1077

00:52:52,838 --> 00:52:58,268
in the feed that came back to earth

1078

00:52:55,088 --> 00:53:01,328
we're not sure but I was lucky enough to

1079

00:52:58,268 --> 00:53:04,689
be on the the Uvas team the ultraviolet

1080

00:53:01,329 --> 00:53:06,849
imaging spectrograph team so we were

1081

00:53:04,690 --> 00:53:08,920
like okay well we took some moon just to

1082

00:53:06,849 --> 00:53:12,519
let they're not images but we took data

1083

00:53:08,920 --> 00:53:14,139
let us look at it let me see there's

1084
00:53:12,518 --> 00:53:15,758
evidence that there's something right

1085
00:53:14,139 --> 00:53:17,469
around here

1086
00:53:15,759 --> 00:53:19,208
the infrared instrument does the same

1087
00:53:17,469 --> 00:53:21,009
the radio science instrument does the

1088
00:53:19,208 --> 00:53:23,978
same and we all confirm that this

1089
00:53:21,009 --> 00:53:26,289
whatever it was right here is there I

1090
00:53:23,978 --> 00:53:29,348
wasn't just something weird that imaging

1091
00:53:26,289 --> 00:53:33,940
picked up so we go to work on it we

1092
00:53:29,349 --> 00:53:36,789
realized that it's a plume it's a series

1093
00:53:33,940 --> 00:53:41,798
of geysers that are erupting out of the

1094
00:53:36,789 --> 00:53:45,849
South Pole of Enceladus now Enceladus by

1095
00:53:41,798 --> 00:53:48,099
all accounts is yes it is the brightest

1096
00:53:45,849 --> 00:53:54,400
thing in our solar system because it's

1097
00:53:48,099 --> 00:53:56,709
covered in pure white ice but it's it's

1098
00:53:54,400 --> 00:54:00,309
small it's only like 250 kilometers

1099
00:53:56,708 --> 00:54:04,058
across that that ice looks to be really

1100
00:54:00,309 --> 00:54:08,140
really thick why would it have geologic

1101
00:54:04,059 --> 00:54:10,089
activity that would cause a geyser but

1102
00:54:08,139 --> 00:54:12,608
we've done studies we've we flown with

1103
00:54:10,088 --> 00:54:17,078
Cassini flew by and sell it as many many

1104
00:54:12,608 --> 00:54:19,748
many times and we mapped it out these

1105
00:54:17,079 --> 00:54:21,519
geysers were there these geysers changed

1106
00:54:19,748 --> 00:54:25,238
position over the course of the Cassini

1107
00:54:21,518 --> 00:54:27,218
mission they gave us evidence that

1108
00:54:25,239 --> 00:54:31,088
there's possibly liquid under the

1109
00:54:27,219 --> 00:54:34,539
surface and that these icy worlds that

1110
00:54:31,088 --> 00:54:38,048
seemed geologically dead are really

1111
00:54:34,539 --> 00:54:40,239
interesting and active we had hinted at

1112

00:54:38,048 --> 00:54:42,298
this before we weren't quite sure when

1113
00:54:40,239 --> 00:54:48,009
we got there we we saw and salad us

1114
00:54:42,298 --> 00:54:48,480
buried in the earring embedded in the

1115
00:54:48,009 --> 00:54:50,159
ear

1116
00:54:48,480 --> 00:54:52,320
and we thought well maybe that's why

1117
00:54:50,159 --> 00:54:54,539
it's so bright it's in a ring of ice and

1118
00:54:52,320 --> 00:54:58,289
it gets the ice dropped on it every day

1119
00:54:54,539 --> 00:55:01,769
and that's what happens but now we

1120
00:54:58,289 --> 00:55:05,039
realize that ring is there because the

1121
00:55:01,769 --> 00:55:07,108
plumes feed it it is created by

1122
00:55:05,039 --> 00:55:09,630
Enceladus itself and some of this is

1123
00:55:07,108 --> 00:55:13,259
spewing out all the contents of that

1124
00:55:09,630 --> 00:55:17,358
ring so that gives us a new a new

1125
00:55:13,260 --> 00:55:20,190
outlook on how rings are created okay I

1126
00:55:17,358 --> 00:55:22,019

mean like I said it's probably you know

1127

00:55:20,190 --> 00:55:25,530

we got some really close-up images after

1128

00:55:22,019 --> 00:55:28,710

that all these various geysers happening

1129

00:55:25,530 --> 00:55:30,930

all the time they you know I don't know

1130

00:55:28,710 --> 00:55:34,619

who's a who scene act actually seen Old

1131

00:55:30,929 --> 00:55:36,889

Faithful in in real life okay you know

1132

00:55:34,619 --> 00:55:41,309

it goes up maybe a couple hundred feet

1133

00:55:36,889 --> 00:55:44,279

at this highest point this however goes

1134

00:55:41,309 --> 00:55:48,900

up kilometres on you know it goes out

1135

00:55:44,280 --> 00:55:51,349

almost as tall as Enceladus is wide so

1136

00:55:48,900 --> 00:55:55,740

that's how it feeds the e-ring it's it's

1137

00:55:51,349 --> 00:55:58,170

phenomenal and we realize tracing back

1138

00:55:55,739 --> 00:56:00,750

the dynamics of how that must work that

1139

00:55:58,170 --> 00:56:03,150

there must be underneath this thick ice

1140

00:56:00,750 --> 00:56:06,210

shell of Enceladus some sort of

1141
00:56:03,150 --> 00:56:11,579
hemispheric sized lake of liquid water

1142
00:56:06,210 --> 00:56:13,079
that's feeding it and it stays warm so

1143
00:56:11,579 --> 00:56:14,849
then we start looking we think oh well

1144
00:56:13,079 --> 00:56:18,150
if that one's active let's look around

1145
00:56:14,849 --> 00:56:20,880
the solar system people of four years

1146
00:56:18,150 --> 00:56:24,119
loved Europa around Jupiter and we

1147
00:56:20,880 --> 00:56:26,608
thought oh you OPA could have subsurface

1148
00:56:24,119 --> 00:56:29,099
activity we think that there has a thin

1149
00:56:26,608 --> 00:56:31,858
ice shell based on on gravitational data

1150
00:56:29,099 --> 00:56:33,769
from the Galileo spacecraft we think

1151
00:56:31,858 --> 00:56:36,088
that it probably has a subsurface ocean

1152
00:56:33,769 --> 00:56:39,000
let's look at it see if it has any

1153
00:56:36,088 --> 00:56:42,710
geysers so Hubble looked at it and BAM

1154
00:56:39,000 --> 00:56:45,119
sure enough we see evidence for water in

1155
00:56:42,710 --> 00:56:47,460
certain areas at certain points at its

1156
00:56:45,119 --> 00:56:49,800
orbit which means it probably has some

1157
00:56:47,460 --> 00:56:52,769
kind of periodic geyser that's coming

1158
00:56:49,800 --> 00:56:54,269
out of again its South Pole now we're

1159
00:56:52,769 --> 00:56:57,150
not sure on the South Pole connection

1160
00:56:54,269 --> 00:56:58,530
but that's interesting and so you get

1161
00:56:57,150 --> 00:57:01,150
something that's kind of like this

1162
00:56:58,530 --> 00:57:04,510
artist's impression of what it might be

1163
00:57:01,150 --> 00:57:07,298
to stand on the surface of Europa a guys

1164
00:57:04,510 --> 00:57:08,890
are coming out of an ice field kind of

1165
00:57:07,298 --> 00:57:15,278
feels like you're in Iceland it's very

1166
00:57:08,889 --> 00:57:18,038
cool and you know the alternative is you

1167
00:57:15,278 --> 00:57:21,250
could trap a little little under under

1168
00:57:18,039 --> 00:57:24,430
crust lakes full of this stuff there's

1169

00:57:21,250 --> 00:57:30,539
the crux of it is there is heat below

1170
00:57:24,429 --> 00:57:33,639
the ice heat means energy liquid water

1171
00:57:30,539 --> 00:57:36,549
increases the potential for life to

1172
00:57:33,639 --> 00:57:40,598
exist so if there's energy and liquid

1173
00:57:36,548 --> 00:57:42,579
water perhaps there's life and as we're

1174
00:57:40,599 --> 00:57:45,430
thinking about our definition of what

1175
00:57:42,579 --> 00:57:47,859
earth 2.0 might look like what another

1176
00:57:45,429 --> 00:57:50,169
earth might look like perhaps we should

1177
00:57:47,858 --> 00:57:53,710
be expanding our definition maybe it

1178
00:57:50,170 --> 00:57:54,639
shouldn't just be a planet that is the

1179
00:57:53,710 --> 00:57:57,400
size of Earth

1180
00:57:54,639 --> 00:57:59,558
that's one AU from a Sun it's a g2 type

1181
00:57:57,400 --> 00:58:03,730
star maybe we should start thinking

1182
00:57:59,559 --> 00:58:05,829
about ice worlds and moons around giant

1183
00:58:03,730 --> 00:58:07,659

planets and those sorts of things so as

1184

00:58:05,829 --> 00:58:10,450

we look across our solar system and as

1185

00:58:07,659 --> 00:58:12,969

we look at other exoplanets we need to

1186

00:58:10,449 --> 00:58:15,759

have this in mind so we now Cassini has

1187

00:58:12,969 --> 00:58:17,608

given us this great gift of expanding

1188

00:58:15,760 --> 00:58:21,849

our vocabulary

1189

00:58:17,608 --> 00:58:24,009

- what habitable means so I promised you

1190

00:58:21,849 --> 00:58:29,109

a timeline just to put this all in

1191

00:58:24,010 --> 00:58:31,480

context again we had almost 20 years ago

1192

00:58:29,108 --> 00:58:35,170

to the day in two weeks it'll be 20

1193

00:58:31,480 --> 00:58:37,449

years ago the launch of the Cassini

1194

00:58:35,170 --> 00:58:41,260

mission Cassini and Huygens together and

1195

00:58:37,449 --> 00:58:43,808

there were five known exoplanets so

1196

00:58:41,260 --> 00:58:47,799

Cassini was truly just a Saturn mission

1197

00:58:43,809 --> 00:58:54,490

it was there to learn more about Saturn

1198
00:58:47,798 --> 00:58:57,099
as a planet then when in July 2004 when

1199
00:58:54,489 --> 00:59:00,568
Cassini got to Saturn and did its

1200
00:58:57,099 --> 00:59:05,019
orbital insertion there were 12

1201
00:59:00,568 --> 00:59:07,630
exoplanets 12 I remember that feeling of

1202
00:59:05,019 --> 00:59:10,659
oh this is about to happen this is so

1203
00:59:07,630 --> 00:59:12,548
exciting but Cassini's still just a

1204
00:59:10,659 --> 00:59:13,828
Saturn mission but it will be really

1205
00:59:12,548 --> 00:59:17,969
cool if we learn about why

1206
00:59:13,829 --> 00:59:22,109
fifteen or twenty exoplanets and then in

1207
00:59:17,969 --> 00:59:24,719
between 2004 and today we've had the

1208
00:59:22,108 --> 00:59:26,518
Kepler mission we've had Hubble looking

1209
00:59:24,719 --> 00:59:28,858
at stuff we've had lots of ground-based

1210
00:59:26,518 --> 00:59:33,659
campaigns looking for other worlds and

1211
00:59:28,858 --> 00:59:37,139
so today we know of over 3,600

1212
00:59:33,659 --> 00:59:39,179
exoplanets with so many more planned to

1213
00:59:37,139 --> 00:59:41,909
be observed those are on small patches

1214
00:59:39,179 --> 00:59:44,009
of the sky we know more exists when you

1215
00:59:41,909 --> 00:59:46,768
look up in the sky at night you know

1216
00:59:44,009 --> 00:59:48,449
that for every star you see out there on

1217
00:59:46,768 --> 00:59:52,588
average there's at least one planet

1218
00:59:48,449 --> 00:59:54,509
around that star and so now we can apply

1219
00:59:52,588 --> 00:59:56,849
these lessons we've learned over the

1220
00:59:54,509 --> 01:00:00,900
course of the Cassini mission to all of

1221
00:59:56,849 --> 01:00:04,200
those worlds especially since some of

1222
01:00:00,900 --> 01:00:07,039
those systems have more than one planet

1223
01:00:04,199 --> 01:00:09,748
so we're looking at at you know

1224
01:00:07,039 --> 01:00:11,789
ecosystems whole solar systems that are

1225
01:00:09,748 --> 01:00:14,699
forming in much the same way that

1226

01:00:11,789 --> 01:00:17,700
perhaps the Saturn system did and we can

1227
01:00:14,699 --> 01:00:20,879
apply those lessons to figure out how

1228
01:00:17,699 --> 01:00:22,078
how these worlds form and like I said

1229
01:00:20,880 --> 01:00:24,358
you know we know of even more

1230
01:00:22,079 --> 01:00:29,278
protoplanetary discs these discs where

1231
01:00:24,358 --> 01:00:32,608
planets form so getting back to that

1232
01:00:29,278 --> 01:00:34,978
first slide so these icy moons we've

1233
01:00:32,608 --> 01:00:36,958
learned are geologically active with the

1234
01:00:34,978 --> 01:00:40,649
Cassini mission and this has given us

1235
01:00:36,958 --> 01:00:43,018
the idea that they are bastions for life

1236
01:00:40,650 --> 01:00:45,989
we need to start looking there if we

1237
01:00:43,018 --> 01:00:50,338
want to find life beyond Earth we have

1238
01:00:45,989 --> 01:00:52,019
seen planetary rings that are ancient

1239
01:00:50,338 --> 01:00:55,588
they probably formed with the planet

1240
01:00:52,018 --> 01:00:58,439

they are active on short short

1241
01:00:55,588 --> 01:01:03,449
timescales and they are dynamic they're

1242
01:00:58,440 --> 01:01:06,358
constantly changing these are a model

1243
01:01:03,449 --> 01:01:10,199
for how worlds are both built and

1244
01:01:06,358 --> 01:01:14,869
destroyed in our system and beyond and

1245
01:01:10,199 --> 01:01:19,289
the weather the storms the incredible

1246
01:01:14,869 --> 01:01:22,920
complexity of Saturn's atmosphere has

1247
01:01:19,289 --> 01:01:25,109
helped us understand that the

1248
01:01:22,920 --> 01:01:26,460
atmospheres of other giant planets are

1249
01:01:25,108 --> 01:01:30,568
just as Kampa

1250
01:01:26,460 --> 01:01:33,240
dynamic and we can't have one computer

1251
01:01:30,568 --> 01:01:35,550
modeling code that we use as scientists

1252
01:01:33,239 --> 01:01:40,618
to model all of those worlds beyond our

1253
01:01:35,550 --> 01:01:43,530
own so really what it comes down to with

1254
01:01:40,619 --> 01:01:47,579
the Cassini mission is using our own

1255
01:01:43,530 --> 01:01:49,829
natural laboratory in our backyard for

1256
01:01:47,579 --> 01:01:53,220
answering questions that are fundamental

1257
01:01:49,829 --> 01:01:55,730
to us as human beings how did we get

1258
01:01:53,219 --> 01:01:59,879
here looking at the Rings

1259
01:01:55,730 --> 01:02:03,269
how does the universe work looking at

1260
01:01:59,880 --> 01:02:06,900
things like storms on Saturn and are we

1261
01:02:03,269 --> 01:02:11,250
alone looking at icy worlds beyond our

1262
01:02:06,900 --> 01:02:14,099
own so I think that the legacy of the

1263
01:02:11,250 --> 01:02:15,869
Cassini mission will be felt for years

1264
01:02:14,099 --> 01:02:17,940
and years

1265
01:02:15,869 --> 01:02:19,710
there are many research projects that

1266
01:02:17,940 --> 01:02:23,480
have yet to be done with the data

1267
01:02:19,710 --> 01:02:26,940
Cassini collected and many that have

1268
01:02:23,480 --> 01:02:29,699
results that have yet to be fully felt

1269
01:02:26,940 --> 01:02:32,849
and impacted in other branches of

1270
01:02:29,699 --> 01:02:36,509
astronomy so I think as we go forward

1271
01:02:32,849 --> 01:02:42,150
together as humans and as a scientific

1272
01:02:36,510 --> 01:02:44,880
community we can really come back to the

1273
01:02:42,150 --> 01:02:45,568
Cassini mission and thank it for

1274
01:02:44,880 --> 01:02:48,230
everything

1275
01:02:45,568 --> 01:02:48,230
it gave us

1276
01:02:48,800 --> 01:03:04,369
[Applause]

1277
01:03:22,849 --> 01:03:25,940
[Music]

1278
01:03:33,599 --> 01:03:39,179
[Music]

1279
01:04:24,500 --> 01:04:32,659
[Music]

1280
01:04:26,230 --> 01:04:48,340
in some cases so there's a couple of

1281
01:04:32,659 --> 01:04:48,339
things does the water come from

1282
01:04:49,579 --> 01:04:52,829
[Music]

1283

01:04:53,460 --> 01:04:58,869
so I'd be a little bit at history before

1284
01:04:56,800 --> 01:05:02,410
we got there with Cassini we thought

1285
01:04:58,869 --> 01:05:09,489
that the reasons were likely delivered

1286
01:05:02,409 --> 01:05:12,250
by comments comments we know they were

1287
01:05:09,489 --> 01:05:15,159
probably streaking by these out of the

1288
01:05:12,250 --> 01:05:19,449
system sound was big enough that they

1289
01:05:15,159 --> 01:05:26,199
got close enough rip it apart and voila

1290
01:05:19,449 --> 01:05:28,329
you've got a ring there were different

1291
01:05:26,199 --> 01:05:30,339
people debating how one thinks one so

1292
01:05:28,329 --> 01:05:34,539
comments must there have been to create

1293
01:05:30,340 --> 01:05:36,760
such vibrant rings and if the if this

1294
01:05:34,539 --> 01:05:38,739
gets true and these would still have

1295
01:05:36,760 --> 01:05:41,350
hadn't been pretty like rings less

1296
01:05:38,739 --> 01:05:43,719
massive then they would have over time

1297
01:05:41,349 --> 01:05:47,619

dating to those little ring part of the

1298

01:05:43,719 --> 01:05:50,739

spiral into Saturn until that time read

1299

01:05:47,619 --> 01:05:53,589

was depleted in there wasn't a time

1300

01:05:50,739 --> 01:05:57,009

scale on that was something around 50 to

1301

01:05:53,590 --> 01:06:02,530

100 million years so roughly the age of

1302

01:05:57,010 --> 01:06:05,470

the dinosaurs well why then are we lucky

1303

01:06:02,530 --> 01:06:07,360

enough as human beings on a planet in

1304

01:06:05,469 --> 01:06:09,309

the Solar System is last billions of

1305

01:06:07,360 --> 01:06:12,700

years why are we lucky enough to be able

1306

01:06:09,309 --> 01:06:15,190

to see this now so that's when we are

1307

01:06:12,699 --> 01:06:18,699

against the being young but there's one

1308

01:06:15,190 --> 01:06:21,519

is for the ancients we got there and so

1309

01:06:18,699 --> 01:06:22,149

now we see that they are not quite

1310

01:06:21,519 --> 01:06:25,900

agents

1311

01:06:22,150 --> 01:06:27,400

ancient both spectroscopically and by

1312
01:06:25,900 --> 01:06:31,180
the dynamics we see we see them

1313
01:06:27,400 --> 01:06:32,710
effectively recycle so things booms

1314
01:06:31,179 --> 01:06:36,219
build-up and they break apart

1315
01:06:32,710 --> 01:06:38,349
so rather than all these vertical

1316
01:06:36,219 --> 01:06:39,789
spiraling inward because they're

1317
01:06:38,349 --> 01:06:42,329
possibly particles they come together

1318
01:06:39,789 --> 01:06:46,840
and there's kind of like a reservoir of

1319
01:06:42,329 --> 01:06:50,880
ice which then you smash back part of

1320
01:06:46,840 --> 01:06:50,880
process repeats so

1321
01:07:00,068 --> 01:07:05,288
well then our baby how still our Daniel

1322
01:07:03,009 --> 01:07:07,539
plantation where when you put that ice

1323
01:07:05,289 --> 01:07:14,769
and water initiative come from the

1324
01:07:07,539 --> 01:07:20,319
currents most likes idea is that the

1325
01:07:14,768 --> 01:07:25,598
initial system so something similar in

1326
01:07:20,318 --> 01:07:28,599
size Titan probably had half a dozen of

1327
01:07:25,599 --> 01:07:33,329
these and they so slowly moved in closer

1328
01:07:28,599 --> 01:07:44,240
to Saturn and we're over time by pies

1329
01:07:33,329 --> 01:07:50,670
and replanted so that makes sense to us

1330
01:07:44,239 --> 01:07:50,669
[Music]

1331
01:08:21,500 --> 01:08:29,060
[Music]

1332
01:08:30,179 --> 01:08:49,989
so which is assault so so yeah lots of

1333
01:08:47,349 --> 01:08:52,359
lots of stuff in there I know some of

1334
01:08:49,988 --> 01:08:53,709
the stuff that most recently in the in

1335
01:08:52,359 --> 01:08:57,338
the plumes that they're they're finding

1336
01:08:53,710 --> 01:09:03,670
are in that plume besides water they're

1337
01:08:57,338 --> 01:09:05,229
finding exist in what what are under see

1338
01:09:03,670 --> 01:09:07,899
underwater events

1339
01:09:05,229 --> 01:09:12,159
on earth these deep ocean vents where we

1340

01:09:07,899 --> 01:09:14,769
see lots of life very small bacteria all

1341
01:09:12,159 --> 01:09:19,088
the way to like little blind crayfish

1342
01:09:14,770 --> 01:09:22,630
and that kind of thing so finding

1343
01:09:19,088 --> 01:09:25,630
evidence of those sorts of materials in

1344
01:09:22,630 --> 01:09:28,088
the plume lets us know where the plumes

1345
01:09:25,630 --> 01:09:31,239
may be coming from ultimately and that's

1346
01:09:28,088 --> 01:09:33,220
really exciting and and I think carbon

1347
01:09:31,238 --> 01:09:35,369
carbon is is one of those that would

1348
01:09:33,220 --> 01:09:38,770
give us evidence of them happening

1349
01:09:35,369 --> 01:09:40,509
farther down deep down and the kinds of

1350
01:09:38,770 --> 01:09:44,700
materials that are at those undersea

1351
01:09:40,509 --> 01:09:44,699
vents okay other questions

1352
01:09:54,600 --> 01:10:05,739
does it ever change not that we've seen

1353
01:09:59,189 --> 01:10:11,500
so far in all of our observations we

1354
01:10:05,738 --> 01:10:16,839

haven't seen we there was some evidence

1355

01:10:11,500 --> 01:10:25,119

of the hexagon I mean they're both

1356

01:10:16,840 --> 01:10:27,850

ground-based observations and Voyager so

1357

01:10:25,119 --> 01:10:29,289

we thought it was there which now builds

1358

01:10:27,850 --> 01:10:32,260

up evidence of you know something more

1359

01:10:29,289 --> 01:10:39,609

like 40 years of it being there and our

1360

01:10:32,260 --> 01:10:54,090

resolution wasn't good enough to know so

1361

01:10:39,609 --> 01:10:54,089

yeah so we think it's okay the points of

1362

01:11:00,300 --> 01:11:05,909

like the storms around

1363

01:11:14,880 --> 01:11:19,929

a question about the end of the Cassini

1364

01:11:17,618 --> 01:11:21,368

mission how deep did it get before it

1365

01:11:19,929 --> 01:11:39,609

burned up and did we get some useful

1366

01:11:21,368 --> 01:11:43,658

data but unfortunately because of how I

1367

01:11:39,609 --> 01:11:48,488

was going in we tried to position it so

1368

01:11:43,658 --> 01:11:51,308

that would send back data but there

1369
01:11:48,488 --> 01:11:53,498
wasn't much time for that the data that

1370
01:11:51,309 --> 01:11:55,929
comes back from my Cassini mission as a

1371
01:11:53,498 --> 01:12:00,309
men in deep space missions you were

1372
01:11:55,929 --> 01:12:05,109
called New Horizons was this way to very

1373
01:12:00,309 --> 01:12:06,639
very slow trickle of data so that's why

1374
01:12:05,109 --> 01:12:09,368
we first saw Cluedo with New Horizons

1375
01:12:06,639 --> 01:12:10,569
and still rainy and fuzzy and he had to

1376
01:12:09,368 --> 01:12:12,698
wait a couple of weeks

1377
01:12:10,569 --> 01:12:15,748
that wasn't just data processing that

1378
01:12:12,698 --> 01:12:20,788
was actually getting the data to earth

1379
01:12:15,748 --> 01:12:20,788
the interplanetary Internet is like your

1380
01:12:21,710 --> 01:12:24,819
[Music]

1381
01:12:34,719 --> 01:12:49,090
the Hurricanes are short-lived is the

1382
01:12:38,560 --> 01:12:50,969
polar hurricane short-lived that was

1383
01:12:49,090 --> 01:12:53,920
that was there the northern latitudes

1384
01:12:50,969 --> 01:13:12,130
around who does that affect the hexagon

1385
01:12:53,920 --> 01:13:13,600
shape extra cold winter but I'm not that

1386
01:13:12,130 --> 01:13:16,560
I will say I don't understand sure

1387
01:13:13,600 --> 01:13:16,560
because I'm not an expert

1388
01:13:23,460 --> 01:13:29,460
there's a theory that you robo's water

1389
01:13:27,069 --> 01:13:32,049
is liquid it's because of the

1390
01:13:29,460 --> 01:13:34,600
interaction between it and Jupiter the

1391
01:13:32,050 --> 01:13:38,920
gravitational pull of two places if that

1392
01:13:34,600 --> 01:13:42,850
is also true between Saturday until

1393
01:13:38,920 --> 01:13:47,100
Enceladus is it's water due to

1394
01:13:42,850 --> 01:13:47,100
gravitational interactions with Saturn

1395
01:13:50,219 --> 01:13:55,539
the inner grab the gravitational

1396
01:13:52,779 --> 01:13:59,259
interaction kind of the title impression

1397

01:13:55,539 --> 01:14:01,289
that happens same way we have tides on

1398
01:13:59,260 --> 01:14:01,289
earth

1399
01:14:03,310 --> 01:14:07,870
something similar happens with Jupiter

1400
01:14:05,319 --> 01:14:10,599
it's way better and its moons which are

1401
01:14:07,869 --> 01:14:15,789
a little bit smaller so effectively it

1402
01:14:10,600 --> 01:14:20,400
squeezes those moons and that squeezing

1403
01:14:15,789 --> 01:14:20,399
that has energy to this and that energy

1404
01:14:21,000 --> 01:14:29,729
I do Kirby sense because these are very

1405
01:14:27,429 --> 01:14:29,730
close

1406
01:14:48,529 --> 01:15:49,789
[Music]

1407
01:14:50,770 --> 01:15:56,960
so are we really that fortunate and if

1408
01:15:49,789 --> 01:15:58,699
so you look at robot Wow to be living in

1409
01:15:56,960 --> 01:16:01,340
a time where both of those are active

1410
01:15:58,699 --> 01:16:03,889
and this or maybe the the actual

1411
01:16:01,340 --> 01:16:06,199

situation is that this activity is just

1412

01:16:03,890 --> 01:16:09,110
ongoing it always happens and we're not

1413

01:16:06,199 --> 01:16:17,210
special so sorry scientists tend to

1414

01:16:09,109 --> 01:16:21,229
think we're not special hexagons image

1415

01:16:17,210 --> 01:16:23,930
and about forefathers Oh with a fuzzy

1416

01:16:21,229 --> 01:16:25,369
white dot and about nine o'clock with a

1417

01:16:23,930 --> 01:16:29,360
funny little loop like a little

1418

01:16:25,369 --> 01:16:33,569
miniature spacecraft actually what

1419

01:16:29,359 --> 01:16:33,569
[Laughter]

1420

01:16:38,010 --> 01:16:43,570
the hexagon image about four o'clock

1421

01:16:41,350 --> 01:16:49,740
there's there's some kind of let me just

1422

01:16:43,569 --> 01:16:49,739
slide back at four o'clock there is

1423

01:16:53,640 --> 01:16:58,980
there we go yeah okay

1424

01:16:56,920 --> 01:17:06,880
I four o'clock there's this thing I

1425

01:16:58,979 --> 01:17:09,189
don't know that's five o'clock there's

1426
01:17:06,880 --> 01:17:12,720
this kind of blobby thing and then over

1427
01:17:09,189 --> 01:17:15,250
here at nine o'clock there's this thing

1428
01:17:12,720 --> 01:17:18,250
what's going on

1429
01:17:15,250 --> 01:17:20,890
well this is this this is definitely

1430
01:17:18,250 --> 01:17:23,340
some sort of other storm and disturbance

1431
01:17:20,890 --> 01:17:25,810
that's happening within this structure

1432
01:17:23,340 --> 01:17:28,690
this isn't a you know this is a shape

1433
01:17:25,810 --> 01:17:30,550
but this isn't the shape here this

1434
01:17:28,689 --> 01:17:33,849
definition of the shape doesn't control

1435
01:17:30,550 --> 01:17:37,150
what's happening in here it sits like a

1436
01:17:33,850 --> 01:17:39,039
wall and it can find some of the things

1437
01:17:37,149 --> 01:17:42,939
inside of that wall but it doesn't have

1438
01:17:39,039 --> 01:17:45,789
necessarily make things happen in that

1439
01:17:42,939 --> 01:17:47,769
wall so so this this storm this is a

1440
01:17:45,789 --> 01:17:52,539
storm it may not be related to the

1441
01:17:47,770 --> 01:17:54,820
hexagonal and this I don't I don't know

1442
01:17:52,539 --> 01:17:58,649
that maybe that's I don't know maybe

1443
01:17:54,819 --> 01:17:58,649
that's an artifact I have no idea

1444
01:18:24,770 --> 01:18:27,849
[Music]

1445
01:18:50,949 --> 01:18:54,010
[Music]

1446
01:19:01,680 --> 01:19:10,270
we clean clean by our standards from

1447
01:19:07,390 --> 01:19:23,289
when we don't want to accidentally

1448
01:19:10,270 --> 01:19:35,050
smacking into one of these moons and the

1449
01:19:23,289 --> 01:19:38,729
folks at Mars for similar reasons so

1450
01:19:35,050 --> 01:19:38,730
this is this is all along

1451
01:20:05,460 --> 01:20:09,380
[Music]

1452
01:20:24,140 --> 01:21:06,329
we are yes you mentioned in your

1453
01:21:03,300 --> 01:21:09,779
presentation that hurricanes feed on

1454

01:21:06,329 --> 01:21:11,939
heat this is anymore

1455
01:21:09,779 --> 01:21:12,569
they sing hurricane what is the energy

1456
01:21:11,939 --> 01:21:14,159
source

1457
01:21:12,569 --> 01:21:16,229
okay so hurricanes if you don't heat

1458
01:21:14,159 --> 01:21:21,869
what's the energy source to power the

1459
01:21:16,229 --> 01:21:23,750
polar vortex here so just because it's

1460
01:21:21,869 --> 01:21:25,989
northern facing

1461
01:21:23,750 --> 01:21:28,069
it was facing away from the something

1462
01:21:25,989 --> 01:21:30,710
that's that's the first one

1463
01:21:28,069 --> 01:21:33,229
but Saturn itself has a lot of internal

1464
01:21:30,710 --> 01:21:35,630
heat that's all the giant planets had a

1465
01:21:33,229 --> 01:21:37,369
lot of internal there they're far away

1466
01:21:35,630 --> 01:21:42,770
from the Sun it really doesn't matter

1467
01:21:37,369 --> 01:21:44,449
how much they're warmed by the Sun but

1468
01:21:42,770 --> 01:21:46,430

for this particular thing it matters

1469

01:21:44,449 --> 01:21:47,359

more than that the internal tank is

1470

01:21:46,430 --> 01:21:52,300

there

1471

01:21:47,359 --> 01:21:52,299

Saturn is actually super interesting

1472

01:21:52,810 --> 01:22:03,080

it's very dense lots of gas layers and

1473

01:21:57,520 --> 01:22:05,630

AB something that big eventually kind of

1474

01:22:03,079 --> 01:22:08,689

settles out the different gas layers

1475

01:22:05,630 --> 01:22:12,500

settle out or over the lifetime of the

1476

01:22:08,689 --> 01:22:14,799

planet some of the the heavier elements

1477

01:22:12,500 --> 01:22:18,079

that are in the outer layers settle down

1478

01:22:14,800 --> 01:22:22,630

so basically what can happen at Saturn

1479

01:22:18,079 --> 01:22:28,449

as you could have liquid helium rain

1480

01:22:22,630 --> 01:22:36,650

into the inner layers of Saturn and that

1481

01:22:28,449 --> 01:22:38,979

energy those things falling when we look

1482

01:22:36,649 --> 01:22:43,429

at Jupiter for example another example

1483
01:22:38,979 --> 01:22:46,669
Jupiter's output of energy is greater

1484
01:22:43,430 --> 01:22:49,850
than its input the energy reserves from

1485
01:22:46,670 --> 01:22:53,739
the Sun is less than what we see

1486
01:22:49,850 --> 01:22:56,270
radiating back out for the same reason

1487
01:22:53,739 --> 01:22:57,769
okay we've got time for only one more

1488
01:22:56,270 --> 01:23:00,610
question do we have any kids in the

1489
01:22:57,770 --> 01:23:00,610
question

1490
01:23:05,380 --> 01:23:09,630
here's been waiting the whole time to

1491
01:23:07,810 --> 01:23:12,070
get the honor of the last question sorry

1492
01:23:09,630 --> 01:23:14,829
might apply the interest with extra

1493
01:23:12,069 --> 01:23:17,349
biology and I'm just wondering what are

1494
01:23:14,829 --> 01:23:20,429
the odds for life on the movies and and

1495
01:23:17,350 --> 01:23:20,429
are we going to send something

1496
01:23:30,719 --> 01:23:33,460
specifically to look at those moons for

1497
01:23:32,948 --> 01:23:36,638
life

1498
01:23:33,460 --> 01:23:39,698
good question end with yeah I would rank

1499
01:23:36,639 --> 01:23:42,760
the moons of the solar system in terms

1500
01:23:39,698 --> 01:23:46,869
of probability of life as Europa and

1501
01:23:42,760 --> 01:23:48,699
sell it as tighten your rope up because

1502
01:23:46,869 --> 01:23:54,369
it probably has the most heat the

1503
01:23:48,698 --> 01:23:57,339
shallowest crust and the the largest

1504
01:23:54,369 --> 01:24:00,729
rocky core that could support some sort

1505
01:23:57,340 --> 01:24:03,579
of chemoautotrophs type organism at a

1506
01:24:00,729 --> 01:24:06,009
and a deep-sea event for example but I

1507
01:24:03,579 --> 01:24:09,698
can't put numbers on probability for

1508
01:24:06,010 --> 01:24:12,940
that the way to confirm this would be to

1509
01:24:09,698 --> 01:24:15,698
actually go there with a submarine

1510
01:24:12,939 --> 01:24:18,250
that's what I would like maybe something

1511

01:24:15,698 --> 01:24:20,079
that could land drill down but you know

1512
01:24:18,250 --> 01:24:22,510
even an orbiter or something would be

1513
01:24:20,079 --> 01:24:25,210
very cool the problem with that is the

1514
01:24:22,510 --> 01:24:27,400
Jupiter system full of radiation you

1515
01:24:25,210 --> 01:24:31,210
have to do with the Juno mission does

1516
01:24:27,399 --> 01:24:32,738
come in quickly and go way far out come

1517
01:24:31,210 --> 01:24:34,810
in quickly and go far out or else your

1518
01:24:32,738 --> 01:24:37,138
electronics are fried so this is one of

1519
01:24:34,810 --> 01:24:39,400
the tough things about a Europa mission

1520
01:24:37,139 --> 01:24:40,810
which makes which makes the Saturn

1521
01:24:39,399 --> 01:24:44,198
system a little more enticing less

1522
01:24:40,810 --> 01:24:46,120
radiation there but I think in the

1523
01:24:44,198 --> 01:24:49,569
community's opinion maybe less likely to

1524
01:24:46,119 --> 01:24:52,090
find life so what we can keep doing is

1525
01:24:49,569 --> 01:24:55,229

we can keep compiling evidence as

1526

01:24:52,090 --> 01:24:58,449

scientists we we want evidence and

1527

01:24:55,229 --> 01:25:01,209

there's never necessarily a smoking gun

1528

01:24:58,448 --> 01:25:05,039

unless we were to go there and pick up a

1529

01:25:01,210 --> 01:25:05,039

what you know so

1530

01:25:06,329 --> 01:25:13,389

that was got one strong mission yeah

1531

01:25:09,779 --> 01:25:15,099

yeah but I would just echo I would echo

1532

01:25:13,389 --> 01:25:17,289

what she said is that you know when we

1533

01:25:15,100 --> 01:25:19,510

explored Mars we first sent an orbiter

1534

01:25:17,289 --> 01:25:22,149

alright and then we started to send to

1535

01:25:19,510 --> 01:25:23,560

send Landers and then Rovers etc it's

1536

01:25:22,149 --> 01:25:24,670

kind of if we're gonna explore any of

1537

01:25:23,560 --> 01:25:26,800

these moons it's got to be the same

1538

01:25:24,670 --> 01:25:28,810

thing we've got us in orbiters to map

1539

01:25:26,800 --> 01:25:31,179

all the places that we might want to

1540
01:25:28,810 --> 01:25:33,280
land and then Landers and then Rovers

1541
01:25:31,179 --> 01:25:35,920
and then diggers and submarines and such

1542
01:25:33,279 --> 01:25:37,929
so it's not gonna happen next year it's

1543
01:25:35,920 --> 01:25:40,329
not gonna happen this decade it's a long

1544
01:25:37,929 --> 01:25:42,850
term process all right so we have to

1545
01:25:40,329 --> 01:25:46,840
stop you there next month's talk will be

1546
01:25:42,850 --> 01:25:49,270
on dangerous worlds so we'll take this

1547
01:25:46,840 --> 01:25:51,219
even further lazy now let's give a real

1548
01:25:49,270 --> 01:25:53,460
big warm thank you for dr. Bonnie my

1549
01:25:51,219 --> 01:25:53,460
team

1550
01:25:59,639 --> 01:26:05,159
okay last thing ireenie

1551
01:26:02,760 --> 01:26:09,179
a rainy rate raised your hand Irene II

1552
01:26:05,158 --> 01:26:11,488
can take what 15 people okay I know

1553
01:26:09,179 --> 01:26:14,579
there's way too many than more than 15

1554
01:26:11,488 --> 01:26:16,529
but when you have enough just go do you

1555
01:26:14,579 --> 01:26:18,779
want to hang hang out by this store okay

1556
01:26:16,529 --> 01:26:20,189
Irene ease gonna hang by this store when

1557
01:26:18,779 --> 01:26:21,960
she has enough she'll take him across

1558
01:26:20,189 --> 01:26:23,939
the street for observing and if you

1559
01:26:21,960 --> 01:26:25,980
don't make it this month come back again

1560
01:26:23,939 --> 01:26:27,689
she'll do it every every month it says

1561
01:26:25,979 --> 01:26:30,169
clear thank you all and see you in

1562
01:26:27,689 --> 01:26:30,169
November

1563
01:27:00,198 --> 01:27:02,259
you