

1
00:00:00,000 --> 00:00:04,080
good evening ladies and gentlemen and

2
00:00:01,439 --> 00:00:06,629
welcome to the Space Telescope public

3
00:00:04,080 --> 00:00:08,189
lecture series I'm your host dr. Frank

4
00:00:06,628 --> 00:00:11,039
summers of the office of public outreach

5
00:00:08,189 --> 00:00:14,219
and it is my pleasure to welcome you

6
00:00:11,039 --> 00:00:16,549
here as you came in you might have

7
00:00:14,218 --> 00:00:19,320
picked up one of our lithographs

8
00:00:16,550 --> 00:00:22,199
tonight's lithograph is a supernova

9
00:00:19,320 --> 00:00:24,329
remnant a the remnant of a explosion of

10
00:00:22,199 --> 00:00:26,220
a star looks like a nice red bubble

11
00:00:24,329 --> 00:00:29,698
matter of fact its nickname is the red

12
00:00:26,219 --> 00:00:31,410
bubble its supernova remnant Oh 509 and

13
00:00:29,699 --> 00:00:34,079
I think there's actually more than two

14
00:00:31,410 --> 00:00:35,219
the name of it but anyways if you would

15
00:00:34,079 --> 00:00:37,829
like to know more about it

16
00:00:35,219 --> 00:00:39,899
turn over on the back and read the text

17
00:00:37,829 --> 00:00:43,410
there that our office public outreach

18
00:00:39,899 --> 00:00:44,759
has put there for you our speaker

19
00:00:43,409 --> 00:00:47,968
tonight we'll be talking about

20
00:00:44,759 --> 00:00:52,079
supernovae chasing supernovae with

21
00:00:47,969 --> 00:00:54,600
Kepler marvelous repurposing of a

22
00:00:52,079 --> 00:00:56,128
satellite to do all sorts of science

23
00:00:54,600 --> 00:00:58,879
it's really kind of cool decay to all

24
00:00:56,128 --> 00:01:01,979
the all the different k2 mission

25
00:00:58,878 --> 00:01:04,948
upcoming now this has changed okay

26
00:01:01,979 --> 00:01:07,170
I had a cancellation and I refilled it

27
00:01:04,948 --> 00:01:09,959
and I've gotten new stuff here so on

28
00:01:07,170 --> 00:01:13,349
November which is the second Tuesday the

29

00:01:09,959 --> 00:01:15,959
first Tuesday is election day so go vote

30
00:01:13,349 --> 00:01:18,688
don't come here go vote and on the

31
00:01:15,959 --> 00:01:21,298
second Tuesday whether your party wins

32
00:01:18,688 --> 00:01:23,908
or loses come here and learn about

33
00:01:21,299 --> 00:01:26,939
observing with Hubble from scientific

34
00:01:23,909 --> 00:01:30,530
idea to published result and everything

35
00:01:26,938 --> 00:01:32,908
in between okay Bill Blair said it has a

36
00:01:30,530 --> 00:01:35,700
he's been having a lot of fun preparing

37
00:01:32,909 --> 00:01:37,469
this talk and if he did really

38
00:01:35,700 --> 00:01:41,609
everything in between it'd probably be a

39
00:01:37,469 --> 00:01:44,609
17-month talk so I think he'll condense

40
00:01:41,609 --> 00:01:47,489
it just a little bit for us in December

41
00:01:44,609 --> 00:01:50,849
Mark kamionkowski has volunteered to do

42
00:01:47,489 --> 00:01:55,109
his talk on black holes and other dark

43
00:01:50,849 --> 00:01:57,868

matters two of the most popular topics

44

00:01:55,109 --> 00:02:01,950

in astronomy you won't want to miss this

45

00:01:57,868 --> 00:02:04,438

one and in January note it's the third

46

00:02:01,950 --> 00:02:06,420

Tuesday the first Tuesday is New Year's

47

00:02:04,438 --> 00:02:09,209

Day so we're not going to do it then the

48

00:02:06,420 --> 00:02:11,098

second Tuesday happens during the

49

00:02:09,209 --> 00:02:13,610

American Astronomical Society meeting

50

00:02:11,098 --> 00:02:16,669

which is the largest astronomical

51

00:02:13,610 --> 00:02:18,700

of the year so we're skipping that one

52

00:02:16,669 --> 00:02:21,530

and we're doing it on the third Tuesday

53

00:02:18,699 --> 00:02:23,329

and we're this is a really cool stuff

54

00:02:21,530 --> 00:02:25,879

that actually will probably be talked

55

00:02:23,330 --> 00:02:28,310

about a lot at the AAAS meeting initial

56

00:02:25,879 --> 00:02:30,319

exoplanet discoveries with Tess Tessa's

57

00:02:28,310 --> 00:02:33,530

and knew the transiting exoplanet survey

58
00:02:30,319 --> 00:02:35,719
satellite brand new discoveries really

59
00:02:33,530 --> 00:02:39,469
cool stuff and Scott Fleming will be

60
00:02:35,719 --> 00:02:43,819
talking about them all right so if you

61
00:02:39,469 --> 00:02:47,000
want all the details website if you go

62
00:02:43,819 --> 00:02:49,430
to hubble site you'll find us on there

63
00:02:47,000 --> 00:02:50,900
you can use your web browser and search

64
00:02:49,430 --> 00:02:53,180
for Hubble public talks and you should

65
00:02:50,900 --> 00:02:54,950
find this we have links to our web

66
00:02:53,180 --> 00:02:58,400
casting we have links to our past

67
00:02:54,949 --> 00:03:01,569
lectures you can sign up for our email

68
00:02:58,400 --> 00:03:04,400
list and get all the information there

69
00:03:01,569 --> 00:03:06,620
our email are just basically two

70
00:03:04,400 --> 00:03:08,420
announcements a month if you can't sign

71
00:03:06,620 --> 00:03:09,849
up at the website you write your name on

72
00:03:08,419 --> 00:03:12,379
a piece of paper hand it to me

73
00:03:09,849 --> 00:03:14,750
I'll make sure you get on there and

74
00:03:12,379 --> 00:03:16,189
again as always if you have comments or

75
00:03:14,750 --> 00:03:21,949
questions you can send them to the email

76
00:03:16,189 --> 00:03:23,329
address public lecture at stsci edu for

77
00:03:21,949 --> 00:03:25,939
those of you who do social media we're

78
00:03:23,330 --> 00:03:28,250
on Facebook Twitter YouTube Instagram I

79
00:03:25,939 --> 00:03:31,579
myself of a lot I'm on those sometimes

80
00:03:28,250 --> 00:03:33,860
if you sort of find that this is mostly

81
00:03:31,580 --> 00:03:36,860
for the web audience and they can pause

82
00:03:33,860 --> 00:03:39,860
it and copy down these addresses all

83
00:03:36,860 --> 00:03:42,050
right the observatory is not open

84
00:03:39,860 --> 00:03:44,090
tonight because it's under repair okay

85
00:03:42,050 --> 00:03:45,950
it's actually probably it looks like it

86

00:03:44,090 --> 00:03:47,870
was a reasonable reasonable night for it

87
00:03:45,949 --> 00:03:50,689
somebody say all right now not quite all

88
00:03:47,870 --> 00:03:53,209
right so maybe it wasn't but it's not

89
00:03:50,689 --> 00:03:55,639
open anyways so you'll have to go to MD

90
00:03:53,209 --> 00:03:58,550
that space granorg check out their

91
00:03:55,639 --> 00:04:00,079
Friday night open houses while it's

92
00:03:58,550 --> 00:04:02,090
under repair I'm assuming they're not

93
00:04:00,080 --> 00:04:04,219
going to have it but if you go to that

94
00:04:02,090 --> 00:04:06,769
webpage there and check the observatory

95
00:04:04,219 --> 00:04:08,780
status you will be able to find out

96
00:04:06,769 --> 00:04:12,230
whether they are doing observing each

97
00:04:08,780 --> 00:04:13,039
and every Friday night we have a special

98
00:04:12,229 --> 00:04:15,889
announcement

99
00:04:13,039 --> 00:04:17,180
because Space Telescope and NASA are

100
00:04:15,889 --> 00:04:20,389

working with a Maryland Institute

101

00:04:17,180 --> 00:04:22,819

College of Art mica on a special

102

00:04:20,389 --> 00:04:25,519

presentation called painting the sky in

103

00:04:22,819 --> 00:04:27,409

gamma-rays celebrating 10

104

00:04:25,519 --> 00:04:30,168

years of the Fermi gamma-ray Space

105

00:04:27,410 --> 00:04:33,020

Telescope and there's one thing you can

106

00:04:30,168 --> 00:04:35,689

say about mica you may not love what

107

00:04:33,019 --> 00:04:39,079

they do but it's never boring

108

00:04:35,689 --> 00:04:41,439

okay and so mica is now taking on gamma

109

00:04:39,079 --> 00:04:43,758

rays all right when is this happening

110

00:04:41,439 --> 00:04:46,658

the bottom half of this advertisement

111

00:04:43,759 --> 00:04:49,788

tells you it's on Sunday October 14th

112

00:04:46,658 --> 00:04:52,009

the doors open at 6:30 the show is at

113

00:04:49,788 --> 00:04:54,969

7:00 all of the artwork and everything

114

00:04:52,009 --> 00:04:57,408

has been curated by both artists and

115
00:04:54,970 --> 00:04:59,599
astronomers or some and the presentation

116
00:04:57,408 --> 00:05:01,908
will be by both of them so it should be

117
00:04:59,598 --> 00:05:03,529
an interesting evening and what you see

118
00:05:01,908 --> 00:05:06,310
down here at the bottom is the Baltimore

119
00:05:03,529 --> 00:05:10,429
skyline and above it is the gamma-ray

120
00:05:06,310 --> 00:05:13,579
all-sky map from Fermi so gamma rays and

121
00:05:10,430 --> 00:05:17,120
mica all right if you want to attend

122
00:05:13,579 --> 00:05:19,639
that and now the news from the universe

123
00:05:17,120 --> 00:05:22,340
not for September of 2018 I obviously

124
00:05:19,639 --> 00:05:28,629
didn't change this slide today haha but

125
00:05:22,339 --> 00:05:31,538
for October 2018 first story tonight

126
00:05:28,629 --> 00:05:34,908
gravitational lensing and buffalo wings

127
00:05:31,538 --> 00:05:39,439
as you all know I love coming up with

128
00:05:34,908 --> 00:05:42,649
interesting titles so a few years ago I

129
00:05:39,439 --> 00:05:45,439
ran a visualization wall here in the

130
00:05:42,649 --> 00:05:46,968
building it wasn't this big but the

131
00:05:45,439 --> 00:05:49,278
point of a visualization wall is that

132
00:05:46,968 --> 00:05:51,319
you can see lots and lots and lots of

133
00:05:49,278 --> 00:05:53,598
pixels matter of fact my visualization

134
00:05:51,319 --> 00:05:54,979
wall was the only place in the building

135
00:05:53,598 --> 00:05:57,769
that you could see the brand-new

136
00:05:54,978 --> 00:06:00,860
advanced camera survey images pixel for

137
00:05:57,769 --> 00:06:04,339
pixel so I got to see a lot of the

138
00:06:00,860 --> 00:06:06,500
really fresh data straight off off the

139
00:06:04,339 --> 00:06:09,439
telescope because people would bring it

140
00:06:06,500 --> 00:06:11,629
to my office and they look at it and one

141
00:06:09,439 --> 00:06:14,839
of the most amazing images I ever got to

142
00:06:11,629 --> 00:06:18,649
see was the original image of this get

143

00:06:14,839 --> 00:06:22,068
galaxy cluster Abell 1689 this is a

144
00:06:18,649 --> 00:06:24,829
massive galaxy cluster so massive that

145
00:06:22,069 --> 00:06:26,689
the mass of the cluster distorts space

146
00:06:24,829 --> 00:06:28,639
and produces an effect called

147
00:06:26,689 --> 00:06:30,288
gravitational lensing okay

148
00:06:28,639 --> 00:06:33,139
so light that passes through that

149
00:06:30,288 --> 00:06:36,079
cluster gets stretched and warped and

150
00:06:33,139 --> 00:06:38,838
magnified and amplified in strange ways

151
00:06:36,079 --> 00:06:39,439
and you see these streaky are key things

152
00:06:38,838 --> 00:06:42,319
I mean

153
00:06:39,439 --> 00:06:44,750
in on it okay you can see all these

154
00:06:42,319 --> 00:06:47,360
strange streaks and arcs those are the

155
00:06:44,750 --> 00:06:49,279
gravitationally lensed galaxies galaxies

156
00:06:47,360 --> 00:06:51,920
behind the cluster whose light has been

157
00:06:49,279 --> 00:06:54,529

stretched out while it passes through

158

00:06:51,920 --> 00:06:56,660

the cluster and when Mark postman

159

00:06:54,529 --> 00:06:58,250

brought this into my office we looked at

160

00:06:56,660 --> 00:07:00,710

it and we were like floored because

161

00:06:58,250 --> 00:07:03,529

there was gravitational lensing across

162

00:07:00,709 --> 00:07:05,870

the entire image all the way out to the

163

00:07:03,529 --> 00:07:08,329

edges and which really meant that you

164

00:07:05,870 --> 00:07:10,399

know Hubble is capturing a lot of really

165

00:07:08,329 --> 00:07:13,250

great gravitational lensing but there's

166

00:07:10,399 --> 00:07:15,949

still more to see outside of this beyond

167

00:07:13,250 --> 00:07:18,379

Hubble's field of view and that has been

168

00:07:15,949 --> 00:07:20,659

true for a lot of the gravitationally

169

00:07:18,379 --> 00:07:22,279

lens clusters we've looked at one of the

170

00:07:20,660 --> 00:07:25,939

ones we've looked at the most often has

171

00:07:22,279 --> 00:07:28,639

been galaxy cluster Abell 370 okay and

172
00:07:25,939 --> 00:07:32,149
it's really famous because it has the

173
00:07:28,639 --> 00:07:34,759
dragon all right so this gravitationally

174
00:07:32,149 --> 00:07:37,819
lensed arc is actually like a it's three

175
00:07:34,759 --> 00:07:40,519
or five images of the same galaxy but

176
00:07:37,819 --> 00:07:42,110
all stretched out together in a form

177
00:07:40,519 --> 00:07:43,819
that somebody'd nicknamed the dragon

178
00:07:42,110 --> 00:07:49,610
okay and that's sort of what made a bell

179
00:07:43,819 --> 00:07:51,589
370 famous but just like with 1689 we

180
00:07:49,610 --> 00:07:53,680
look at it and we see the gravitational

181
00:07:51,589 --> 00:07:56,239
lensing there but we don't get to see

182
00:07:53,680 --> 00:07:57,590
what's around it although gravity all

183
00:07:56,240 --> 00:08:01,730
the full extent of the gravitational

184
00:07:57,589 --> 00:08:04,939
lensing until a brand-new project has

185
00:08:01,730 --> 00:08:07,100
has come up and it has her tortured

186
00:08:04,939 --> 00:08:10,730
record him like a lot of astronomy

187
00:08:07,100 --> 00:08:14,629
projects beyond ultra deep frontier

188
00:08:10,730 --> 00:08:16,790
fields and legacy observations yes

189
00:08:14,629 --> 00:08:19,699
they got buffalo together even to that

190
00:08:16,790 --> 00:08:22,069
as their academic so the Buffalo Survey

191
00:08:19,699 --> 00:08:25,129
which is a project to try and you know

192
00:08:22,069 --> 00:08:26,870
extend out and really get gravitational

193
00:08:25,129 --> 00:08:29,719
lensing as well as Hubble can do it

194
00:08:26,870 --> 00:08:32,750
they've looked at a Bell 370 and instead

195
00:08:29,720 --> 00:08:35,719
of this region they are taking that much

196
00:08:32,750 --> 00:08:37,250
region in okay so this is their first

197
00:08:35,719 --> 00:08:39,169
image that they've released from the

198
00:08:37,250 --> 00:08:41,179
project just say hey the project is

199
00:08:39,168 --> 00:08:42,500
going and we're getting really good data

200

00:08:41,179 --> 00:08:45,289
and we're seeing things and what we're

201
00:08:42,500 --> 00:08:47,240
able to do is look out and see not just

202
00:08:45,289 --> 00:08:49,129
the really strong lensing in the center

203
00:08:47,240 --> 00:08:50,960
but you get as you get further and

204
00:08:49,129 --> 00:08:52,919
further out if you've got strong lensing

205
00:08:50,960 --> 00:08:55,319
here and you go further out it becomes

206
00:08:52,919 --> 00:08:57,448
we cleansing right so you're going from

207
00:08:55,318 --> 00:08:59,938
a strongly means toward the we cleansing

208
00:08:57,448 --> 00:09:02,308
rosy regime and were able to get much

209
00:08:59,938 --> 00:09:04,649
better observations and understanding of

210
00:09:02,308 --> 00:09:06,539
the distribution of mass in this cluster

211
00:09:04,649 --> 00:09:08,669
which is what gravitational lensing

212
00:09:06,539 --> 00:09:10,558
really tells you about cuz you can see

213
00:09:08,669 --> 00:09:12,988
where the galaxies are but where is the

214
00:09:10,558 --> 00:09:15,509

mass and in particular the dark matter

215

00:09:12,989 --> 00:09:17,819

of the universe how is that distributed

216

00:09:15,509 --> 00:09:19,918

and so the Buffalo project will be able

217

00:09:17,818 --> 00:09:22,558

to do that on larger scales giving us

218

00:09:19,918 --> 00:09:24,989

finer details and more understanding of

219

00:09:22,558 --> 00:09:27,499

the largest collapsed structures in the

220

00:09:24,989 --> 00:09:31,019

universe these giant galaxies clusters

221

00:09:27,499 --> 00:09:33,540

so the joke is of course that by looking

222

00:09:31,019 --> 00:09:36,509

in the wings in the buffalo wings of the

223

00:09:33,539 --> 00:09:39,629

cluster we're going to get a lot of new

224

00:09:36,509 --> 00:09:43,949

information yeah I'm sorry I had had to

225

00:09:39,629 --> 00:09:49,079

do that alright our second story for you

226

00:09:43,948 --> 00:09:51,118

tonight our solar system grows again aha

227

00:09:49,078 --> 00:09:53,998

everyone thinks we know all about our

228

00:09:51,119 --> 00:09:56,129

solar system we're still discovering in

229
00:09:53,999 --> 00:09:57,569
our solar system because you know when

230
00:09:56,129 --> 00:09:59,159
people think of the solar system they

231
00:09:57,568 --> 00:10:01,708
think of the Sun and the eight planets

232
00:09:59,159 --> 00:10:03,600
okay that's the central region of our

233
00:10:01,708 --> 00:10:05,458
solar system we've got you know the four

234
00:10:03,600 --> 00:10:07,470
rocky planets in close the four giant

235
00:10:05,458 --> 00:10:10,078
planets out there and that's your basic

236
00:10:07,470 --> 00:10:12,480
picture of the solar system but if

237
00:10:10,078 --> 00:10:14,938
you've been paying attention you will

238
00:10:12,480 --> 00:10:16,769
know that in the 1990s we started

239
00:10:14,938 --> 00:10:19,110
discovering a whole new region of the

240
00:10:16,769 --> 00:10:22,470
solar system and it's called the Kuiper

241
00:10:19,110 --> 00:10:24,269
belt okay and those are the orbits of

242
00:10:22,470 --> 00:10:27,178
Jupiter Saturn Uranus and Neptune and

243
00:10:24,269 --> 00:10:30,749
all those red and white dots have been

244
00:10:27,178 --> 00:10:33,269
discovered since 1992 thousands of

245
00:10:30,749 --> 00:10:35,129
objects there's small icy earth

246
00:10:33,269 --> 00:10:38,548
elliptical orbits and tilted orbit set

247
00:10:35,129 --> 00:10:41,009
cetera and Pluto is the largest of the

248
00:10:38,548 --> 00:10:42,568
Kuiper belt objects okay sorry it's not

249
00:10:41,009 --> 00:10:44,188
a planet anymore but it's it's now the

250
00:10:42,568 --> 00:10:46,649
king of the Kuiper belt if you want to

251
00:10:44,188 --> 00:10:48,389
you know feel good about it okay and if

252
00:10:46,649 --> 00:10:50,879
you've really been paying attention you

253
00:10:48,389 --> 00:10:53,068
know that the Kuiper belt isn't it we

254
00:10:50,879 --> 00:10:55,589
also have a region of the solar system

255
00:10:53,068 --> 00:10:57,178
that we've never seen directly but we

256
00:10:55,589 --> 00:11:00,839
sort of seen indirectly it's the Oort

257

00:10:57,178 --> 00:11:03,178
cloud and this is a logarithmic plot so

258
00:11:00,839 --> 00:11:06,150
you can see the Orcas way way way out it

259
00:11:03,178 --> 00:11:09,629
goes out to like 50 thousand a

260
00:11:06,149 --> 00:11:12,449
whereas the earth is 1au and neptune is

261
00:11:09,629 --> 00:11:15,240
30 au and the Kuiper belt goes to 50 au

262
00:11:12,450 --> 00:11:19,080
this goes a thousand times farther out

263
00:11:15,240 --> 00:11:21,389
to 50,000 au okay and this is where the

264
00:11:19,080 --> 00:11:23,970
long period comets come from all right

265
00:11:21,389 --> 00:11:26,490
so there's a lot more to our solar

266
00:11:23,970 --> 00:11:28,889
system than you usually think and we

267
00:11:26,490 --> 00:11:30,049
hadn't really gone out beyond the Kuiper

268
00:11:28,889 --> 00:11:34,230
belt

269
00:11:30,049 --> 00:11:37,409
except we found this one strange object

270
00:11:34,230 --> 00:11:40,139
in the 90s it's not in the early 2000s

271
00:11:37,409 --> 00:11:42,360

it's called Sedna now up in the top

272

00:11:40,139 --> 00:11:44,279

there you see the orbits of the giant

273

00:11:42,360 --> 00:11:45,269

planets and I think that purple one is

274

00:11:44,279 --> 00:11:47,819

the orbit of Pluto

275

00:11:45,269 --> 00:11:50,490

okay so Pluto gives you the the scale of

276

00:11:47,820 --> 00:11:54,270

the Kuiper belt you can see said nações

277

00:11:50,490 --> 00:11:57,810

way way way out Sedna at its closest is

278

00:11:54,269 --> 00:12:01,559

like 75 au and it goes all the way out

279

00:11:57,809 --> 00:12:04,199

to almost a thousand au what the heck is

280

00:12:01,559 --> 00:12:06,419

it doing there okay it's sort of beyond

281

00:12:04,200 --> 00:12:09,120

the realm of the Kuiper belt but it's

282

00:12:06,419 --> 00:12:11,669

inside the realm of the Oort cloud and

283

00:12:09,120 --> 00:12:13,429

it was really hard to understand how you

284

00:12:11,669 --> 00:12:16,379

could get an object sitting there and

285

00:12:13,429 --> 00:12:19,889

then we found hey you know what

286
00:12:16,379 --> 00:12:22,679
it isn't the only one all of these

287
00:12:19,889 --> 00:12:24,149
objects are you can see Sedna's orbit

288
00:12:22,679 --> 00:12:25,799
here in the dark purple and all the

289
00:12:24,149 --> 00:12:27,600
light purple objects have been

290
00:12:25,799 --> 00:12:29,039
discovered and they have similar object

291
00:12:27,600 --> 00:12:31,259
we got half a dozen or so of these

292
00:12:29,039 --> 00:12:33,449
objects that are sitting out in sort of

293
00:12:31,259 --> 00:12:38,370
a no-man's land of the solar system and

294
00:12:33,450 --> 00:12:41,730
that is what caused Mike Brown and his

295
00:12:38,370 --> 00:12:45,060
colleagues to suppose hypothesize that

296
00:12:41,730 --> 00:12:46,920
there was this actual planet 9 after

297
00:12:45,059 --> 00:12:49,289
getting rid of Pluto is Planet 9 they

298
00:12:46,919 --> 00:12:51,719
brought it back as a hypothesis to

299
00:12:49,289 --> 00:12:53,309
explain all of these orbits that are out

300
00:12:51,720 --> 00:12:55,710
sort of in this no-man's land of the

301
00:12:53,309 --> 00:12:58,259
solar system so they have been looking

302
00:12:55,710 --> 00:13:00,930
for planet 9 for a couple years they

303
00:12:58,259 --> 00:13:04,259
proposed this in 2015 and they've got

304
00:13:00,929 --> 00:13:07,469
some searches underway and yesterday

305
00:13:04,259 --> 00:13:10,259
they announced no they didn't announce

306
00:13:07,470 --> 00:13:16,290
Planet nine but they announced a new

307
00:13:10,259 --> 00:13:18,840
object 2015 TG 387 now take a look at

308
00:13:16,289 --> 00:13:20,750
this scale you see Sedna they're going

309
00:13:18,840 --> 00:13:24,090
out to a thousand au

310
00:13:20,750 --> 00:13:25,980
EEG which is which they call short for

311
00:13:24,090 --> 00:13:28,080
the Goblin TG because it was discovered

312
00:13:25,980 --> 00:13:33,570
around Halloween three years ago goes

313
00:13:28,080 --> 00:13:36,500
out to 2300 au the solar system size of

314

00:13:33,570 --> 00:13:40,620
what we've observed has just doubled

315
00:13:36,500 --> 00:13:42,779
yeah and this what's significant about

316
00:13:40,620 --> 00:13:44,850
this is this is starting to get out to

317
00:13:42,779 --> 00:13:45,269
the area of the inner edge of the Kuiper

318
00:13:44,850 --> 00:13:51,779
belt

319
00:13:45,269 --> 00:13:53,699
okay so TG 387 is going out to where the

320
00:13:51,779 --> 00:13:56,309
sort of the inner edge but it still

321
00:13:53,700 --> 00:13:59,370
comes in and is out is sort of well

322
00:13:56,309 --> 00:14:01,319
beyond the Kuiper belt when they analyze

323
00:13:59,370 --> 00:14:03,029
this and it took them three years by the

324
00:14:01,320 --> 00:14:04,740
way to get this orbit okay they

325
00:14:03,029 --> 00:14:06,990
discovered it in 2015 it took them three

326
00:14:04,740 --> 00:14:08,430
years of follow-up observations in order

327
00:14:06,990 --> 00:14:10,590
to determine this up so there's orbit

328
00:14:08,429 --> 00:14:14,759

because it's moving so bloody slowly

329

00:14:10,590 --> 00:14:18,030

okay and when they analyzed it they

330

00:14:14,759 --> 00:14:23,039

found it was it too was consistent with

331

00:14:18,029 --> 00:14:25,230

a hypothesis of Planet 9 so they had

332

00:14:23,039 --> 00:14:27,539

doubled the size of the object of the

333

00:14:25,230 --> 00:14:29,399

the orbits of the things we've seen in

334

00:14:27,539 --> 00:14:31,110

the solar system and they found yet

335

00:14:29,399 --> 00:14:33,480

another object that seems to lend

336

00:14:31,110 --> 00:14:35,519

credence to the hypothesis that there is

337

00:14:33,480 --> 00:14:38,970

this you know several earth mass type

338

00:14:35,519 --> 00:14:40,439

planet out beyond the Kuiper belt they

339

00:14:38,970 --> 00:14:43,830

haven't discovered that yet they're

340

00:14:40,440 --> 00:14:46,500

still going to keep looking but hey our

341

00:14:43,830 --> 00:14:49,860

solar system just got a little bit

342

00:14:46,500 --> 00:14:54,240

bigger we're still discovering things in

343
00:14:49,860 --> 00:14:56,789
our own backyard and on that how big is

344
00:14:54,240 --> 00:14:58,830
the object the object is about 300

345
00:14:56,789 --> 00:15:02,279
kilometers in diameter as an estimate

346
00:14:58,830 --> 00:15:04,080
okay it's not well not well resolved so

347
00:15:02,279 --> 00:15:04,589
it's about 300 kilometers so it might be

348
00:15:04,080 --> 00:15:07,050
spherical

349
00:15:04,590 --> 00:15:11,300
so they actually in the press release

350
00:15:07,049 --> 00:15:13,589
called it an extreme dwarf planet I

351
00:15:11,299 --> 00:15:15,919
deleted that text from this diagram

352
00:15:13,590 --> 00:15:18,720
because I don't think it's justified yet

353
00:15:15,919 --> 00:15:22,379
but it could be a dwarf planet by the

354
00:15:18,720 --> 00:15:24,389
AAA use convention by being 300 it might

355
00:15:22,379 --> 00:15:28,230
be spherical but it might not be at 300

356
00:15:24,389 --> 00:15:32,279
kilometers so we're not quite sure all

357
00:15:28,230 --> 00:15:33,710
the details of it but hey there's still

358
00:15:32,279 --> 00:15:38,860
something new Under the Sun

359
00:15:33,710 --> 00:15:38,860
or at least around the Sun yes question

360
00:15:41,440 --> 00:15:46,430
okay so the question is do they have a

361
00:15:44,600 --> 00:15:48,560
guess about what the composition of

362
00:15:46,429 --> 00:15:50,179
Planet 9 would be it would have to be

363
00:15:48,559 --> 00:15:51,799
several earth masses from what I

364
00:15:50,179 --> 00:15:54,319
understand it's been a while since I've

365
00:15:51,799 --> 00:15:55,759
looked at this in detail but they're

366
00:15:54,320 --> 00:15:58,840
looking at several earth masses which

367
00:15:55,759 --> 00:16:04,490
would be a rocky type planet like Earth

368
00:15:58,840 --> 00:16:06,050
okay one more question up there do I

369
00:16:04,490 --> 00:16:09,379
have any idea what the periastron Oh

370
00:16:06,049 --> 00:16:13,399
Planet nine would be no it's not my

371

00:16:09,379 --> 00:16:15,500
field I'm more cosmology not so says the

372
00:16:13,399 --> 00:16:17,990
so I have to bone up when I do these

373
00:16:15,500 --> 00:16:20,090
presentations but I'm sure you're sure

374
00:16:17,990 --> 00:16:22,430
I'm sure if you look up Planet nine and

375
00:16:20,090 --> 00:16:25,009
such there are several papers available

376
00:16:22,429 --> 00:16:26,239
on it that might be able to show you the

377
00:16:25,009 --> 00:16:28,879
parameter space that they're looking to

378
00:16:26,240 --> 00:16:33,649
try and find this hypothesized object

379
00:16:28,879 --> 00:16:36,649
okay all right and so now we go over to

380
00:16:33,649 --> 00:16:40,340
our featured speaker and our featured

381
00:16:36,649 --> 00:16:42,470
speaker tonight is Gotham Narayan he

382
00:16:40,340 --> 00:16:45,080
came to us for you started out you did

383
00:16:42,470 --> 00:16:49,070
your graduate work at Harvard and then

384
00:16:45,080 --> 00:16:51,980
went to NOAA Oh as a postdoc and then

385
00:16:49,070 --> 00:16:54,379

came here as a Barry Lasker fellow and

386

00:16:51,980 --> 00:16:56,960

is now working in this science mission

387

00:16:54,379 --> 00:16:59,779

office here at the Space Telescope

388

00:16:56,960 --> 00:17:01,070

Science Institute and I'm really looking

389

00:16:59,779 --> 00:17:01,669

forward to this talk so let's give him a

390

00:17:01,070 --> 00:17:03,040

warm hand

391

00:17:01,669 --> 00:17:09,568

Gotha narayan

392

00:17:03,039 --> 00:17:09,568

[Applause]

393

00:17:10,089 --> 00:17:26,509

can you all hear me okay

394

00:17:12,400 --> 00:17:29,180

okay so let's wake this thing up alright

395

00:17:26,509 --> 00:17:32,180

so the title of this talk is chasing

396

00:17:29,180 --> 00:17:33,799

supernovae with Kepler but I learnt very

397

00:17:32,180 --> 00:17:35,570

long ago from Stanley Kubrick that I

398

00:17:33,799 --> 00:17:38,029

should always name things after what

399

00:17:35,569 --> 00:17:39,589

they actually are about so this isn't

400
00:17:38,029 --> 00:17:42,289
really about chasing supernovae with

401
00:17:39,589 --> 00:17:43,819
Kepler it's it's about how we commandeer

402
00:17:42,289 --> 00:17:46,119
the next apparent telescope to go study

403
00:17:43,819 --> 00:17:48,819
stars that will go boom

404
00:17:46,119 --> 00:17:52,369
and that's a much more fun title I think

405
00:17:48,819 --> 00:17:53,809
this isn't a project that I am doing by

406
00:17:52,369 --> 00:17:56,679
myself there's plenty of people working

407
00:17:53,809 --> 00:17:58,819
on it these are a list of the kegerators

408
00:17:56,680 --> 00:18:01,840
collaborators on this experiment called

409
00:17:58,819 --> 00:18:04,700
kegs the Kepler extra galactic Survey

410
00:18:01,839 --> 00:18:06,139
the PI of the project is arm and rest

411
00:18:04,700 --> 00:18:08,180
whoo so the scientist here at Space

412
00:18:06,140 --> 00:18:11,660
Telescope and my mentor and so I'm

413
00:18:08,180 --> 00:18:13,220
talking about all of our work really on

414
00:18:11,660 --> 00:18:16,090
this project it's not it's a team effort

415
00:18:13,220 --> 00:18:18,170
it's a great little project that we have

416
00:18:16,089 --> 00:18:19,819
so to begin with

417
00:18:18,170 --> 00:18:22,820
how many of you have heard of Johannes

418
00:18:19,819 --> 00:18:25,819
Kepler show of hands all right a few of

419
00:18:22,819 --> 00:18:27,139
you okay so let me talk a little bit

420
00:18:25,819 --> 00:18:29,419
about the astronomer of the mission to

421
00:18:27,140 --> 00:18:34,040
solve with Yanis Kepler was the Imperial

422
00:18:29,420 --> 00:18:35,690
mathematician in Graz and he was an

423
00:18:34,039 --> 00:18:37,269
assistant to another famous astronomer

424
00:18:35,690 --> 00:18:41,360
Tycho Brahe he's a contemporary of

425
00:18:37,269 --> 00:18:43,670
Galileo Galilei but he was a smart man

426
00:18:41,359 --> 00:18:45,979
and Galileo for a couple of reasons the

427
00:18:43,670 --> 00:18:47,539
first reason was that Kepler was a very

428

00:18:45,980 --> 00:18:49,190
good optical scientist and learned how

429
00:18:47,539 --> 00:18:51,349
to make really good telescopes in fact

430
00:18:49,190 --> 00:18:54,440
we call most astronomical telescopes

431
00:18:51,349 --> 00:18:56,119
today Keplerian telescopes they have two

432
00:18:54,440 --> 00:18:58,279
convex lenses and this was much better

433
00:18:56,119 --> 00:19:01,009
than Galileo's design of a convex and a

434
00:18:58,279 --> 00:19:03,950
concave lens because it allowed him to

435
00:19:01,009 --> 00:19:06,589
measure distances in angular distances

436
00:19:03,950 --> 00:19:08,900
very precisely he could find the

437
00:19:06,589 --> 00:19:10,879
separation between two stars on the sky

438
00:19:08,900 --> 00:19:13,450
through his telescope much more

439
00:19:10,880 --> 00:19:15,920
precisely than anybody else in his day

440
00:19:13,450 --> 00:19:18,860
that led him to be able to make very

441
00:19:15,920 --> 00:19:19,519
very precise measurements of the motion

442
00:19:18,859 --> 00:19:21,559

of

443

00:19:19,519 --> 00:19:24,079

and planets in the sky he could study

444

00:19:21,559 --> 00:19:25,759

these things very very accurately and he

445

00:19:24,079 --> 00:19:28,039

took very beautiful detailed

446

00:19:25,759 --> 00:19:30,980

measurements off these things recording

447

00:19:28,039 --> 00:19:33,139

them in notebooks so his observations of

448

00:19:30,980 --> 00:19:35,329

the planets in Mars in particular

449

00:19:33,140 --> 00:19:37,790

allowed him to determine something very

450

00:19:35,329 --> 00:19:41,059

important their orbits like you saw for

451

00:19:37,789 --> 00:19:43,279

Sedna and the Goblin in that wonderful

452

00:19:41,059 --> 00:19:45,649

little talk by Frank their orbits

453

00:19:43,279 --> 00:19:47,869

weren't circles right they were

454

00:19:45,650 --> 00:19:50,210

elliptical they were sort of circle

455

00:19:47,869 --> 00:19:52,879

except you take additional direction and

456

00:19:50,210 --> 00:19:54,730

so in his notebook Kepler was the first

457
00:19:52,880 --> 00:19:58,160
person to actually describe this

458
00:19:54,730 --> 00:20:01,519
circular motion this elliptical motion

459
00:19:58,160 --> 00:20:03,529
rather showing you here how a circle

460
00:20:01,519 --> 00:20:05,569
looks versus the geometry of an ellipse

461
00:20:03,529 --> 00:20:08,029
around it this is the second reason that

462
00:20:05,569 --> 00:20:10,460
Kepler is smarter man than Galileo while

463
00:20:08,029 --> 00:20:11,799
Galileo was getting in trouble with the

464
00:20:10,460 --> 00:20:14,120
church for his heretical teachings

465
00:20:11,799 --> 00:20:16,490
Kepler sensibly added angels to his

466
00:20:14,119 --> 00:20:26,599
plots so that kept him on the good side

467
00:20:16,490 --> 00:20:29,599
of things so in honor of Kepler's

468
00:20:26,599 --> 00:20:32,569
pioneering work NASA named it's big

469
00:20:29,599 --> 00:20:34,490
exoplanet flagship mission after him the

470
00:20:32,569 --> 00:20:36,349
Kepler mission this is the Kepler

471
00:20:34,490 --> 00:20:37,970
satellite you actually walked by a model

472
00:20:36,349 --> 00:20:39,889
of this thing as you entered Space

473
00:20:37,970 --> 00:20:42,049
Telescope and as you heading out take a

474
00:20:39,890 --> 00:20:43,370
look and take a look on your left as

475
00:20:42,049 --> 00:20:45,710
you're walking out the glass doors and

476
00:20:43,369 --> 00:20:49,009
you'll see a see there it's a beautiful

477
00:20:45,710 --> 00:20:51,529
thing and this entire mission has been

478
00:20:49,009 --> 00:20:53,059
incredibly successful this isn't of

479
00:20:51,529 --> 00:20:55,609
course the only way we honor Kepler I

480
00:20:53,059 --> 00:21:00,889
named my dog after him as well this is

481
00:20:55,609 --> 00:21:02,889
kept up a dog so let me tell you a

482
00:21:00,890 --> 00:21:05,060
little bit about how Kepler works

483
00:21:02,890 --> 00:21:06,890
that's the satellite over there going

484
00:21:05,059 --> 00:21:08,359
around the Sun and you can see it's

485

00:21:06,890 --> 00:21:10,370
oriented in roughly the same direction

486
00:21:08,359 --> 00:21:12,229
it's pointing at solar cell panels at

487
00:21:10,369 --> 00:21:13,609
towards the Sun at all times and it's

488
00:21:12,230 --> 00:21:17,509
staring in roughly the same direction in

489
00:21:13,609 --> 00:21:19,609
space and it's staring at stars and it's

490
00:21:17,509 --> 00:21:22,940
looking for planets that go around stars

491
00:21:19,609 --> 00:21:25,699
and when a planet does pass in front of

492
00:21:22,940 --> 00:21:27,610
a star what you can see down here is

493
00:21:25,700 --> 00:21:30,680
that the brightness of the star drops

494
00:21:27,609 --> 00:21:32,509
right so this is a how bright the star

495
00:21:30,680 --> 00:21:33,298
is is a function of time so time is

496
00:21:32,509 --> 00:21:37,460
marching this

497
00:21:33,298 --> 00:21:40,918
Way and star goes a front drop come back

498
00:21:37,460 --> 00:21:43,319
and Kepler is seeing hundreds and

499
00:21:40,919 --> 00:21:45,629

thousands of these all the time these

500

00:21:43,319 --> 00:21:49,589

things are called transits and this

501

00:21:45,628 --> 00:21:52,109

particular form of of a plot is of

502

00:21:49,589 --> 00:21:54,058

brightness versus time is something

503

00:21:52,109 --> 00:21:56,099

we'll call a light curves and I'll come

504

00:21:54,058 --> 00:22:00,720

back to why that's important for most of

505

00:21:56,099 --> 00:22:04,168

the stock so this is the capital field

506

00:22:00,720 --> 00:22:07,200

of view and it's found in the course of

507

00:22:04,169 --> 00:22:10,080

its primary mission several thousands of

508

00:22:07,200 --> 00:22:12,028

planets this is our solar system for

509

00:22:10,079 --> 00:22:14,009

scale and as you can see most of the

510

00:22:12,028 --> 00:22:15,749

systems it's finding look nothing like

511

00:22:14,009 --> 00:22:17,970

our solar system our solar systems kind

512

00:22:15,749 --> 00:22:20,399

of odd this might be because the Kepler

513

00:22:17,970 --> 00:22:22,858

is sort of finding planets that are

514
00:22:20,398 --> 00:22:25,108
around hotter stars they're brighter and

515
00:22:22,858 --> 00:22:27,239
also finding bigger planets but it is

516
00:22:25,108 --> 00:22:29,939
still a tremendously successful mission

517
00:22:27,239 --> 00:22:32,038
and it is has been really just an

518
00:22:29,940 --> 00:22:35,999
incredible incredibly revolutionary tool

519
00:22:32,038 --> 00:22:42,358
for our field but I'm not interested in

520
00:22:35,999 --> 00:22:44,940
planets like most kids growing up I was

521
00:22:42,358 --> 00:22:47,460
interested in sci-fi I was interested in

522
00:22:44,940 --> 00:22:51,749
Star Wars I was interested in Star Trek

523
00:22:47,460 --> 00:22:53,669
I loved Superman and so I was left with

524
00:22:51,749 --> 00:22:55,829
this image of what I actually wanted to

525
00:22:53,669 --> 00:22:56,940
happen to planets around stars from

526
00:22:55,829 --> 00:22:59,638
Superman does everybody remember

527
00:22:56,940 --> 00:23:04,470
Superman what planet the super might

528
00:22:59,638 --> 00:23:07,498
come from Krypton so ed shia who is an

529
00:23:04,470 --> 00:23:10,019
astronomer at UMD i was looking as a

530
00:23:07,499 --> 00:23:11,970
some planetary system or what he thought

531
00:23:10,019 --> 00:23:14,548
was battery system and something very

532
00:23:11,970 --> 00:23:18,149
odd happened instead of getting fainter

533
00:23:14,548 --> 00:23:19,980
with the planet going getting you know

534
00:23:18,148 --> 00:23:21,839
causing the light of the star to reduce

535
00:23:19,980 --> 00:23:24,329
when it goes to the front of it this

536
00:23:21,839 --> 00:23:25,558
thing of brighter and he remembered he

537
00:23:24,329 --> 00:23:27,778
said on the state this beautiful quote

538
00:23:25,558 --> 00:23:29,009
and how science works he remembers not

539
00:23:27,778 --> 00:23:31,288
knowing whether he should believe it or

540
00:23:29,009 --> 00:23:32,819
not did I make a mistake am i doing this

541
00:23:31,288 --> 00:23:34,739
all wrong this is hardly what you Rekha

542

00:23:32,819 --> 00:23:36,329
and Archimedes is like but this is

543
00:23:34,739 --> 00:23:39,358
actually how we do science for you we

544
00:23:36,329 --> 00:23:41,460
doubt ourselves all the time but it was

545
00:23:39,358 --> 00:23:43,439
right what he'd found was something that

546
00:23:41,460 --> 00:23:45,389
we had known about for a while

547
00:23:43,440 --> 00:23:46,509
it's a supernova and if you have seen

548
00:23:45,388 --> 00:23:49,148
Superman

549
00:23:46,509 --> 00:23:53,558
recognize this kind of thing so this is

550
00:23:49,148 --> 00:23:55,088
the planet Krypton and in just a second

551
00:23:53,558 --> 00:23:58,028
you should hear Marlon Brando's soothing

552
00:23:55,088 --> 00:23:59,769
voice come over the loudspeakers telling

553
00:23:58,028 --> 00:24:03,368
me telling you that telling his son

554
00:23:59,769 --> 00:24:05,108
kal-el that he will always be around

555
00:24:03,368 --> 00:24:07,509
that's that subin's little cradle

556
00:24:05,108 --> 00:24:09,999

shooting off the world and we're zooming

557

00:24:07,509 --> 00:24:11,769

out here from the planet Krypton in your

558

00:24:09,999 --> 00:24:13,479

life and we're seeing why Krypton is

559

00:24:11,769 --> 00:24:16,058

doomed and why Superman actually happens

560

00:24:13,479 --> 00:24:18,909

listen Superman is happening because the

561

00:24:16,058 --> 00:24:22,028

current Krypton is around a giant red

562

00:24:18,909 --> 00:24:25,079

star that is going to have something

563

00:24:22,028 --> 00:24:25,078

problematic Adam

564

00:24:26,489 --> 00:24:29,489

bounced

565

00:24:35,548 --> 00:24:40,778

that's a supernova that's one things and

566

00:24:39,278 --> 00:24:43,318

as you can see the planet Krypton is not

567

00:24:40,778 --> 00:24:43,318

gonna fare so well

568

00:24:43,409 --> 00:24:51,879

at least and actually pretty accurate

569

00:24:49,108 --> 00:24:55,088

that is actually how quickly a star will

570

00:24:51,878 --> 00:24:55,568

collapse now we've known about supernova

571
00:24:55,088 --> 00:24:57,190
for a while

572
00:24:55,568 --> 00:25:00,368
Kepler himself found this this is the

573
00:24:57,190 --> 00:25:02,889
intro slide again of the talk and this

574
00:25:00,368 --> 00:25:04,808
is from Kepler's own book this is from

575
00:25:02,888 --> 00:25:08,048
his book called a stellar Nova in Paris

576
00:25:04,808 --> 00:25:12,578
serpent ari the new star in the foot of

577
00:25:08,048 --> 00:25:14,019
the serpent over here with an N so back

578
00:25:12,578 --> 00:25:17,348
in a on October 9th

579
00:25:14,019 --> 00:25:18,969
in 1684 a bunch of Italian astronomers

580
00:25:17,348 --> 00:25:20,739
looked up and saw something that they

581
00:25:18,969 --> 00:25:22,449
have never seen before the heavens

582
00:25:20,739 --> 00:25:26,048
changed literally this thing that they

583
00:25:22,449 --> 00:25:28,959
thought was static and incapable of ever

584
00:25:26,048 --> 00:25:31,479
changing and was perfect suddenly had an

585
00:25:28,959 --> 00:25:35,889
F star in it that they could see with

586
00:25:31,479 --> 00:25:37,929
their eyes in day for three weeks they

587
00:25:35,888 --> 00:25:39,758
had no idea what this was well this is a

588
00:25:37,929 --> 00:25:41,229
portent could this mean something

589
00:25:39,759 --> 00:25:43,389
tremendous is going to happen

590
00:25:41,229 --> 00:25:46,298
Kepler with his telescope could study

591
00:25:43,388 --> 00:25:48,248
this for a year he collected not just

592
00:25:46,298 --> 00:25:50,440
observations on it from himself but also

593
00:25:48,249 --> 00:25:52,209
observations from all of the other

594
00:25:50,440 --> 00:25:54,788
astronomers of that time it's one of our

595
00:25:52,209 --> 00:25:58,028
best records of how astronomy was done

596
00:25:54,788 --> 00:25:59,858
in the 17th century and so we know a lot

597
00:25:58,028 --> 00:26:00,440
about this star we know exactly where it

598
00:25:59,858 --> 00:26:01,939
is in sky

599

00:26:00,440 --> 00:26:04,160
we know how bright it was at the time

600
00:26:01,940 --> 00:26:07,610
and how it brightness change dysfunction

601
00:26:04,160 --> 00:26:09,590
of time we know it's light curve and we

602
00:26:07,609 --> 00:26:11,689
can look at it today and this is what is

603
00:26:09,589 --> 00:26:15,049
left of the star that blew up that

604
00:26:11,690 --> 00:26:17,059
Kepler so among others this is a

605
00:26:15,049 --> 00:26:22,460
composite image and I'm going to do the

606
00:26:17,059 --> 00:26:25,990
CSI thing and hit enhance which well

607
00:26:22,460 --> 00:26:29,960
maybe happen if my computer wakes up

608
00:26:25,990 --> 00:26:32,990
there yeah so this is an enhanced view

609
00:26:29,960 --> 00:26:34,460
of the same image and it has four colors

610
00:26:32,990 --> 00:26:38,120
telling you different bits of

611
00:26:34,460 --> 00:26:40,309
information the the blue and the sort of

612
00:26:38,119 --> 00:26:43,069
greenish light are x-ray information

613
00:26:40,309 --> 00:26:46,089

from the Chandra Space Telescope these

614

00:26:43,069 --> 00:26:49,069
are hot highly energetic particles

615

00:26:46,089 --> 00:26:51,500
x-rays shooting out at us the Green is

616

00:26:49,069 --> 00:26:53,809
slightly lower energy the yellow areas

617

00:26:51,500 --> 00:26:55,400
are what we see in the visible this is

618

00:26:53,809 --> 00:26:57,559
with the Hubble Space Telescope where we

619

00:26:55,400 --> 00:27:00,350
see gas and dust left over from the

620

00:26:57,559 --> 00:27:02,089
explosion lit up by a shockwave that

621

00:27:00,349 --> 00:27:04,250
ripped through this entire star and

622

00:27:02,089 --> 00:27:07,429
finally the red is where the shockwave

623

00:27:04,250 --> 00:27:10,880
is today this is where the dust is in my

624

00:27:07,430 --> 00:27:12,680
image by the Spitzer Space Telescope so

625

00:27:10,880 --> 00:27:15,770
this is a really amazing picture you

626

00:27:12,680 --> 00:27:16,910
could see this image of a star that blew

627

00:27:15,769 --> 00:27:19,069
up in Hollywood

628
00:27:16,910 --> 00:27:20,690
and we can actually look at these things

629
00:27:19,069 --> 00:27:23,029
today and find them in the sky and

630
00:27:20,690 --> 00:27:24,410
they're really important because if

631
00:27:23,029 --> 00:27:26,960
you've ever looked at the periodic table

632
00:27:24,410 --> 00:27:29,210
of elements outside of hydrogen and

633
00:27:26,960 --> 00:27:31,549
helium which are produced in the Big

634
00:27:29,210 --> 00:27:34,970
Bang pretty much everything else down

635
00:27:31,549 --> 00:27:36,710
here is from a star so when you hear

636
00:27:34,970 --> 00:27:41,049
somebody like Carl Sagan say you are

637
00:27:36,710 --> 00:27:45,470
made of star stuff this is what he means

638
00:27:41,049 --> 00:27:46,549
every calcium atom in your teeth is from

639
00:27:45,470 --> 00:27:49,779
an exploding star

640
00:27:46,549 --> 00:27:52,250
that's something cool that you should

641
00:27:49,779 --> 00:27:54,889
now supernovae are amazingly bright

642
00:27:52,250 --> 00:27:57,019
things this is a galaxy and if you look

643
00:27:54,890 --> 00:27:59,150
at look down here you'll see a supernova

644
00:27:57,019 --> 00:28:01,400
get brighter over time and fade away

645
00:27:59,150 --> 00:28:02,780
this is its light curve again and you

646
00:28:01,400 --> 00:28:08,960
could sort of see they last for around

647
00:28:02,779 --> 00:28:10,819
30 days you can see them sort of easily

648
00:28:08,960 --> 00:28:12,289
with the telescope like Hubble but I

649
00:28:10,819 --> 00:28:13,759
want you to you know take a step back

650
00:28:12,289 --> 00:28:16,670
and get the big picture here

651
00:28:13,759 --> 00:28:19,730
this is a galaxy with something like 10

652
00:28:16,670 --> 00:28:23,480
to 100 billion stars and this one

653
00:28:19,730 --> 00:28:25,519
supernova was still so bright and so

654
00:28:23,480 --> 00:28:28,099
bright that you could see it against all

655
00:28:25,519 --> 00:28:30,170
of that that's pretty cool

656

00:28:28,099 --> 00:28:33,259
the problem of course is that they are

657
00:28:30,170 --> 00:28:35,480
kind of rare so in a galaxy with a

658
00:28:33,259 --> 00:28:38,720
hundred with ten 200 billion stars you

659
00:28:35,480 --> 00:28:41,529
can still only expect a supernova one or

660
00:28:38,720 --> 00:28:44,900
two supernovae every hundred years or so

661
00:28:41,529 --> 00:28:47,690
so to find these things you've got to

662
00:28:44,900 --> 00:28:49,820
look at lots and lots of galaxies now

663
00:28:47,690 --> 00:28:51,620
the Kepler mission was of course looking

664
00:28:49,819 --> 00:28:53,899
for exoplanets it was staring at one

665
00:28:51,619 --> 00:28:57,169
little patch of sky a little larger than

666
00:28:53,900 --> 00:28:59,090
the full moon and it was continuously

667
00:28:57,170 --> 00:29:01,610
looking at that region of sky for

668
00:28:59,089 --> 00:29:03,289
several years but because it's a small

669
00:29:01,609 --> 00:29:05,389
region of sky because there are

670
00:29:03,289 --> 00:29:07,279

relatively few galaxies in there you are

671

00:29:05,390 --> 00:29:12,410
not going to find a whole lot of

672

00:29:07,279 --> 00:29:13,819
supernovae right that makes sense but we

673

00:29:12,410 --> 00:29:17,120
are gonna get lucky every now and then

674

00:29:13,819 --> 00:29:19,309
so we did find some so these there were

675

00:29:17,119 --> 00:29:21,679
about six supernovae that we found from

676

00:29:19,309 --> 00:29:24,319
2010 to 2012 with Kepler just

677

00:29:21,680 --> 00:29:26,810
fortuitously the kind of supernovae is

678

00:29:24,319 --> 00:29:28,309
that I care about our type 1a supernovas

679

00:29:26,809 --> 00:29:31,059
and this is one of the examples of what

680

00:29:28,309 --> 00:29:32,899
you're seeing here oops

681

00:29:31,059 --> 00:29:35,779
so you see nothing nothing nothing

682

00:29:32,900 --> 00:29:37,310
explosion happens and suddenly there's a

683

00:29:35,779 --> 00:29:44,059
bright increase in the amount of light

684

00:29:37,309 --> 00:29:46,849
from this the Kepler data is spectacular

685
00:29:44,059 --> 00:29:48,980
in many ways from the ground we can

686
00:29:46,849 --> 00:29:53,000
expect typically about 40 observations

687
00:29:48,980 --> 00:29:56,779
of a supernova over its entire 30-days

688
00:29:53,000 --> 00:30:00,019
lifetime what we get with Kepler is

689
00:29:56,779 --> 00:30:02,899
something like 4,000 observations over

690
00:30:00,019 --> 00:30:05,059
its entire lifetime that's just way more

691
00:30:02,900 --> 00:30:07,310
data and in particular that's really

692
00:30:05,059 --> 00:30:11,179
useful because it lets you study just

693
00:30:07,309 --> 00:30:12,889
these sort of areas right before when

694
00:30:11,180 --> 00:30:15,200
the explosion happens and ask the

695
00:30:12,890 --> 00:30:16,940
explosions happening that's an area we

696
00:30:15,200 --> 00:30:19,220
almost can never study from the ground

697
00:30:16,940 --> 00:30:20,660
because we can simply never take enough

698
00:30:19,220 --> 00:30:23,180
images of it from ground-based

699
00:30:20,660 --> 00:30:24,680
telescopes so we found several different

700
00:30:23,180 --> 00:30:26,960
kinds of the supernovae and we've seen

701
00:30:24,680 --> 00:30:28,160
interesting physics from them we've seen

702
00:30:26,960 --> 00:30:30,650
for example

703
00:30:28,160 --> 00:30:33,980
a shock breakout of the star like you

704
00:30:30,650 --> 00:30:35,660
saw in a Hollywood movie and rip apart

705
00:30:33,980 --> 00:30:37,160
this thing and this is something we've

706
00:30:35,660 --> 00:30:39,440
just never been able to do until kept

707
00:30:37,160 --> 00:30:40,820
low but of course the challenge is still

708
00:30:39,440 --> 00:30:44,360
there we're only gonna find a few of

709
00:30:40,819 --> 00:30:45,769
these things so here's a couple of

710
00:30:44,359 --> 00:30:47,299
interesting light curves that we've seen

711
00:30:45,769 --> 00:30:49,069
from Kepler here it's this little bump

712
00:30:47,299 --> 00:30:50,899
that I talked about that's the shark

713

00:30:49,069 --> 00:30:53,450
breaker this is a start exploding

714
00:30:50,900 --> 00:30:55,130
nothing nothing nothing Boop explosion

715
00:30:53,450 --> 00:30:57,529
finally breaking out of the lair of the

716
00:30:55,130 --> 00:31:00,200
star and we just can't do this from the

717
00:30:57,529 --> 00:31:02,089
ground so we really want some way of

718
00:31:00,200 --> 00:31:04,100
hijacking Kepler commandeering Kepler

719
00:31:02,089 --> 00:31:06,829
stopping it from doing so planet science

720
00:31:04,099 --> 00:31:08,959
and doing all supernova science because

721
00:31:06,829 --> 00:31:11,509
this is just tremendous this data is

722
00:31:08,960 --> 00:31:14,058
invaluable for us but unfortunately the

723
00:31:11,509 --> 00:31:17,529
exoplanet people want this thing and

724
00:31:14,058 --> 00:31:19,879
then something horrible happened

725
00:31:17,529 --> 00:31:22,220
just as things were getting interesting

726
00:31:19,880 --> 00:31:24,470
the wheels came off Kepler this was the

727
00:31:22,220 --> 00:31:25,970

headline one of the reaction wheels they

728

00:31:24,470 --> 00:31:26,808

kept the spacecraft pointing in the

729

00:31:25,970 --> 00:31:29,750

right direction

730

00:31:26,808 --> 00:31:32,000

failed suddenly it means three of these

731

00:31:29,750 --> 00:31:33,410

things for your pitch and roll suddenly

732

00:31:32,000 --> 00:31:36,319

it had to keep spinning in one direction

733

00:31:33,410 --> 00:31:38,420

that's a problem that means it no longer

734

00:31:36,319 --> 00:31:41,210

can stay pointed to look for X planets

735

00:31:38,420 --> 00:31:44,000

all the time but that's also not really

736

00:31:41,210 --> 00:31:48,590

finding supernovae of course so we were

737

00:31:44,000 --> 00:31:49,759

you know kind of like that so and this

738

00:31:48,589 --> 00:31:52,220

kind of answers the question Murphy's

739

00:31:49,759 --> 00:31:54,049

Law is greater than Kepler's alright but

740

00:31:52,220 --> 00:31:56,000

this is NASA we're talking about this is

741

00:31:54,049 --> 00:31:57,319

the agency that you know goes where

742
00:31:56,000 --> 00:31:59,720
failure is not an option

743
00:31:57,319 --> 00:32:02,269
and so we have the best boffins there

744
00:31:59,720 --> 00:32:04,160
are and because we have the best puffins

745
00:32:02,269 --> 00:32:07,119
that are we came up with a cool solution

746
00:32:04,160 --> 00:32:11,259
for this this is just the coolest thing

747
00:32:07,119 --> 00:32:14,719
in place of a failed reaction wheel

748
00:32:11,259 --> 00:32:18,039
we're using sunlight to balance the

749
00:32:14,720 --> 00:32:20,539
spacecraft's rotation so the sunlight

750
00:32:18,039 --> 00:32:23,058
exerts a small amount of pressure if

751
00:32:20,539 --> 00:32:25,759
it's unbalanced it can spin that

752
00:32:23,058 --> 00:32:29,629
spacecraft but if it's perfectly

753
00:32:25,759 --> 00:32:34,160
balanced the spacecraft will stay in the

754
00:32:29,630 --> 00:32:36,890
same location despite its lack of react

755
00:32:34,160 --> 00:32:40,040
of that the reaction will so if you

756
00:32:36,890 --> 00:32:41,150
point Kepler just right you can still do

757
00:32:40,039 --> 00:32:43,129
observations with it

758
00:32:41,150 --> 00:32:46,490
with only two reaction wheels with only

759
00:32:43,130 --> 00:32:49,520
this to guide or mode and this is not

760
00:32:46,490 --> 00:32:51,620
ideal if you're looking for exoplanets

761
00:32:49,519 --> 00:32:53,420
you're losing so much position and the

762
00:32:51,619 --> 00:32:55,519
ability to stay pointed exactly on stars

763
00:32:53,420 --> 00:32:56,210
but it's great if you want to find

764
00:32:55,519 --> 00:32:57,799
supernovae

765
00:32:56,210 --> 00:32:59,329
so we finally got rid of the sex of

766
00:32:57,799 --> 00:33:00,829
other people and was like yes we can

767
00:32:59,329 --> 00:33:03,919
totally do this and so we call this new

768
00:33:00,829 --> 00:33:05,960
mission k2 the second light effectively

769
00:33:03,920 --> 00:33:07,850
for k2 and now we can get these

770

00:33:05,960 --> 00:33:11,269
exquisite 30-minute cadence likers

771
00:33:07,849 --> 00:33:13,399
observations every 30 minutes over 100

772
00:33:11,269 --> 00:33:15,079
square degree field of view and we're no

773
00:33:13,400 --> 00:33:17,840
longer looking at just one patch of sky

774
00:33:15,079 --> 00:33:20,839
or we can look at something like 2,000

775
00:33:17,839 --> 00:33:23,899
to 14,000 galaxies every eighty day

776
00:33:20,839 --> 00:33:26,089
campaign with Kepler's k2 mission so

777
00:33:23,900 --> 00:33:28,220
suddenly we go from having a small

778
00:33:26,089 --> 00:33:30,019
number of supernovae to be able able to

779
00:33:28,220 --> 00:33:31,610
finding a lot more supernovae this is

780
00:33:30,019 --> 00:33:33,589
what really happened right this is the

781
00:33:31,609 --> 00:33:34,699
one part of Chi sky Kepler was looking

782
00:33:33,589 --> 00:33:36,740
at where we couldn't find a whole bunch

783
00:33:34,700 --> 00:33:39,740
of supernovae and suddenly now I'd love

784
00:33:36,740 --> 00:33:45,650

to look at a whole range of sky that's

785

00:33:39,740 --> 00:33:47,420

much way better for us and this is great

786

00:33:45,650 --> 00:33:49,490

because on the same sort of you know

787

00:33:47,420 --> 00:33:51,590

scale here's the kind of number of

788

00:33:49,490 --> 00:33:52,670

supernovae we expect to see because

789

00:33:51,589 --> 00:33:55,039

we've been following these with other

790

00:33:52,670 --> 00:33:58,550

telescopes this is every supernova

791

00:33:55,039 --> 00:34:03,549

that's happened in about the last 400

792

00:33:58,549 --> 00:34:05,839

years in 1691 in about 15 seconds

793

00:34:03,549 --> 00:34:07,269

there's a lot of these things if you

794

00:34:05,839 --> 00:34:10,909

look at large enough parts of the sky

795

00:34:07,269 --> 00:34:12,829

that's cool and so we can find a whole

796

00:34:10,909 --> 00:34:14,389

bunch of the supernovae simply because

797

00:34:12,829 --> 00:34:16,969

we're now looking over larger search

798

00:34:14,389 --> 00:34:19,220

area that's this is really tremendously

799

00:34:16,969 --> 00:34:20,779

useful for us and so we can start to do

800

00:34:19,219 --> 00:34:23,148

supernovae science with capital now the

801

00:34:20,780 --> 00:34:24,919

kinds of supernovae I care about aren't

802

00:34:23,148 --> 00:34:27,259

like that collapsing giant star that I

803

00:34:24,918 --> 00:34:30,138

showed you but are rather what happens

804

00:34:27,260 --> 00:34:33,169

when a small remnant a burnt-out remnant

805

00:34:30,139 --> 00:34:35,210

of star called a white dwarf explodes

806

00:34:33,168 --> 00:34:37,579

and it does that in two different ways

807

00:34:35,210 --> 00:34:40,550

it can either steal matter from another

808

00:34:37,579 --> 00:34:42,378

companion star over here or two of these

809

00:34:40,550 --> 00:34:45,710

white dwarfs can get ever closer to each

810

00:34:42,378 --> 00:34:48,199

other spin and then merge and then they

811

00:34:45,710 --> 00:34:50,898

explode once they hit a certain amount

812

00:34:48,199 --> 00:34:54,299

of mass gravity can no longer balanced

813
00:34:50,898 --> 00:34:56,309
sort of internal forces it has

814
00:34:54,300 --> 00:34:57,990
and that are different so these are the

815
00:34:56,309 --> 00:35:00,329
two sort of progenitor channels of

816
00:34:57,989 --> 00:35:02,759
making a type 1a supernova the kind of

817
00:35:00,329 --> 00:35:03,989
thing that I care about and there's also

818
00:35:02,760 --> 00:35:06,570
different kinds of physics that you

819
00:35:03,989 --> 00:35:09,089
might expect so you start off with a

820
00:35:06,570 --> 00:35:10,890
white dwarf and something else and then

821
00:35:09,090 --> 00:35:12,840
somehow or the other you put in some

822
00:35:10,889 --> 00:35:14,460
explosion physics over here and then you

823
00:35:12,840 --> 00:35:16,200
get this thing that blows up called a

824
00:35:14,460 --> 00:35:17,579
supernova and you can study all the

825
00:35:16,199 --> 00:35:21,210
chemical elements that come out of it

826
00:35:17,579 --> 00:35:23,460
from the periodic table and this that's

827

00:35:21,210 --> 00:35:24,900
usually if you can study all the stuff

828
00:35:23,460 --> 00:35:27,510
with Kepler you can really get a handle

829
00:35:24,900 --> 00:35:30,180
on exactly what this question mark is

830
00:35:27,510 --> 00:35:32,400
what's blowing up over here that's the

831
00:35:30,179 --> 00:35:37,230
real question we want to ask what's the

832
00:35:32,400 --> 00:35:39,450
physics of these explosions and so there

833
00:35:37,230 --> 00:35:41,550
are different explosion models some of

834
00:35:39,449 --> 00:35:44,219
these things we think you know go to

835
00:35:41,550 --> 00:35:46,980
roughly around 1.4 times the mass of our

836
00:35:44,219 --> 00:35:48,539
Sun and then ignite near the center some

837
00:35:46,980 --> 00:35:51,030
of these things we think just sort of

838
00:35:48,539 --> 00:35:53,009
have a burst near the explosion near the

839
00:35:51,030 --> 00:35:55,560
surface and some of these things we

840
00:35:53,010 --> 00:35:57,600
think get super heavy and then become

841
00:35:55,559 --> 00:35:59,730

much more energetic explosions and even

842

00:35:57,599 --> 00:36:01,049

a very you know despite the fact that

843

00:35:59,730 --> 00:36:03,150

the physics here is very different than

844

00:36:01,050 --> 00:36:05,430

that Hollywood movie these explosion

845

00:36:03,150 --> 00:36:07,320

simulations have much the same result

846

00:36:05,429 --> 00:36:12,000

the entire star blows up in a few

847

00:36:07,320 --> 00:36:14,369

seconds if you sort of made a grid of

848

00:36:12,000 --> 00:36:15,809

all of those models different kinds of

849

00:36:14,369 --> 00:36:17,940

progenitor scenarios plus different

850

00:36:15,809 --> 00:36:20,009

kinds of explosion models there's a lot

851

00:36:17,940 --> 00:36:21,210

of different options out here I don't

852

00:36:20,010 --> 00:36:23,010

want you to try to read all of these

853

00:36:21,210 --> 00:36:25,079

what I want you to take away is we

854

00:36:23,010 --> 00:36:26,580

actually have no good idea what is

855

00:36:25,079 --> 00:36:28,739

causing these explosions and what we

856
00:36:26,579 --> 00:36:30,420
want to find is which box here is

857
00:36:28,739 --> 00:36:33,449
actually producing these stars this is

858
00:36:30,420 --> 00:36:34,740
what we want to identify and there's

859
00:36:33,449 --> 00:36:36,719
lots and lots of different options for

860
00:36:34,739 --> 00:36:38,429
these things so when we study these

861
00:36:36,719 --> 00:36:39,929
things from the ground we can find lots

862
00:36:38,429 --> 00:36:42,179
and lots of supernovae off different

863
00:36:39,929 --> 00:36:44,039
kinds so we really want to find for each

864
00:36:42,179 --> 00:36:45,899
one of these groups is there a separate

865
00:36:44,039 --> 00:36:48,389
explosion mechanism that's responsible

866
00:36:45,900 --> 00:36:50,099
is that circle with a question mark

867
00:36:48,389 --> 00:36:51,509
different in each of these cases are

868
00:36:50,099 --> 00:36:54,900
they the same are the different

869
00:36:51,510 --> 00:36:56,940
contributions to each of them and we've

870
00:36:54,900 --> 00:36:59,190
simply not really been able to do that

871
00:36:56,940 --> 00:37:01,019
so far easily from the ground it's just

872
00:36:59,190 --> 00:37:05,250
been too hard because we're not studying

873
00:37:01,019 --> 00:37:06,519
supernovae early enough we have some

874
00:37:05,250 --> 00:37:08,679
idea what might

875
00:37:06,519 --> 00:37:12,009
and some ways to distinguish these

876
00:37:08,679 --> 00:37:13,779
models back in 2010 dan casein said I

877
00:37:12,010 --> 00:37:15,940
was an astronomer UC Berkeley said that

878
00:37:13,780 --> 00:37:18,460
if you have a white dwarf blowing up

879
00:37:15,940 --> 00:37:20,950
near some star like our Sun what you

880
00:37:18,460 --> 00:37:22,720
should see at really early times where

881
00:37:20,949 --> 00:37:24,939
Kepler can look another things can't is

882
00:37:22,719 --> 00:37:27,519
an excess of flux in excess of

883
00:37:24,940 --> 00:37:29,409
brightness from material from that white

884

00:37:27,519 --> 00:37:32,469
dwarf running into the companion star

885
00:37:29,409 --> 00:37:34,029
lighting it up so now that gives us a

886
00:37:32,469 --> 00:37:35,529
way of disentangling these different

887
00:37:34,030 --> 00:37:37,119
progenitor scenarios from each other we

888
00:37:35,530 --> 00:37:39,600
can potentially differentiate these

889
00:37:37,119 --> 00:37:43,329
things if we can look at light curves

890
00:37:39,599 --> 00:37:48,309
early enough which again we can really

891
00:37:43,329 --> 00:37:49,569
only do with Kepler meanwhile back on

892
00:37:48,309 --> 00:37:51,159
earth we're getting a little better in

893
00:37:49,570 --> 00:37:52,690
doing this and so we're getting more and

894
00:37:51,159 --> 00:37:55,059
more confident that some of this picture

895
00:37:52,690 --> 00:37:58,510
is right this we've started to find

896
00:37:55,059 --> 00:38:00,519
supernovae where we have some limits on

897
00:37:58,510 --> 00:38:03,369
what these explosions in our your skin

898
00:38:00,519 --> 00:38:06,940

be so this is an image of 2011 F V which

899

00:38:03,369 --> 00:38:09,930

is a supernova and we know from deep

900

00:38:06,940 --> 00:38:12,460

Hubble imaging here that there's no

901

00:38:09,929 --> 00:38:14,980

companion that's larger than the single

902

00:38:12,460 --> 00:38:17,079

solar mass right so there's nothing that

903

00:38:14,980 --> 00:38:20,349

looks like a big star near a white dwarf

904

00:38:17,079 --> 00:38:21,489

in this case that's already one little

905

00:38:20,349 --> 00:38:23,618

piece of evidence that suggests

906

00:38:21,489 --> 00:38:25,929

something is going on and maybe it's one

907

00:38:23,619 --> 00:38:28,090

scenario and not the other you've seen a

908

00:38:25,929 --> 00:38:30,009

few others we've seen cases where there

909

00:38:28,090 --> 00:38:32,710

does look like there's something at the

910

00:38:30,010 --> 00:38:34,900

site of the explosion before the star

911

00:38:32,710 --> 00:38:36,730

blew up so here's the supernova it's

912

00:38:34,900 --> 00:38:38,710

happening in this case for 2012 Z and

913
00:38:36,730 --> 00:38:40,539
here's the site of the explosion you

914
00:38:38,710 --> 00:38:42,519
could see something faint and fuzzy over

915
00:38:40,539 --> 00:38:50,289
here so we know that there's something

916
00:38:42,519 --> 00:38:51,880
there we're not sure what it is there's

917
00:38:50,289 --> 00:38:55,358
some other supernova that we've seen

918
00:38:51,880 --> 00:38:57,190
these these sort of UV excesses in we

919
00:38:55,358 --> 00:38:58,840
think but you can look at how rocky this

920
00:38:57,190 --> 00:39:00,400
ground-based data is compared to that

921
00:38:58,840 --> 00:39:02,950
beautiful Kepler data I showed you

922
00:39:00,400 --> 00:39:04,690
there's almost so much noise over here

923
00:39:02,949 --> 00:39:06,969
we can't be sure of this is just a

924
00:39:04,690 --> 00:39:11,320
random spike or if this is actually a

925
00:39:06,969 --> 00:39:13,569
signal of that excess and finally we've

926
00:39:11,320 --> 00:39:17,390
started to see new things this past year

927
00:39:13,570 --> 00:39:23,900
where again this is 2012 Z oops

928
00:39:17,389 --> 00:39:26,869
skip through that we're right in early

929
00:39:23,900 --> 00:39:28,730
times there's a slight bump over here

930
00:39:26,869 --> 00:39:30,170
and it's a slight bump that might say

931
00:39:28,730 --> 00:39:34,429
that there's some kind of companion over

932
00:39:30,170 --> 00:39:36,530
here so for me trying to understand what

933
00:39:34,429 --> 00:39:40,069
the physics of these progenitor systems

934
00:39:36,530 --> 00:39:43,100
is these are all catalyzing clues but

935
00:39:40,070 --> 00:39:45,080
they're not smoking gun so now would

936
00:39:43,099 --> 00:39:46,699
Kepler back in business with the action

937
00:39:45,079 --> 00:39:49,989
wheel fixed effectively by using the Sun

938
00:39:46,699 --> 00:39:52,489
we can go hunt type 1a supernovae right

939
00:39:49,989 --> 00:39:54,709
the first thing we found didn't look

940
00:39:52,489 --> 00:39:56,959
anything like a type 1a supernova that's

941

00:39:54,710 --> 00:39:59,840
a regular type 1a supernova up here in

942
00:39:56,960 --> 00:40:02,139
blue and what we found was something

943
00:39:59,840 --> 00:40:06,289
that did this way different than that

944
00:40:02,139 --> 00:40:07,699
and we were like who ordered this almond

945
00:40:06,289 --> 00:40:09,980
dressed who's in this building led the

946
00:40:07,699 --> 00:40:12,710
analysis of this and it's a supernova

947
00:40:09,980 --> 00:40:14,690
it's in a galaxy there was nothing there

948
00:40:12,710 --> 00:40:16,369
before and then suddenly it pops up and

949
00:40:14,690 --> 00:40:17,929
disappears and it does that in 14 days

950
00:40:16,369 --> 00:40:19,759
it's very inconsistent with all the

951
00:40:17,929 --> 00:40:21,109
other supernovae we've seen it's also

952
00:40:19,760 --> 00:40:22,970
inconsistent with all the other things

953
00:40:21,110 --> 00:40:25,490
that seemed that we know that sort of

954
00:40:22,969 --> 00:40:28,250
rise up and have relatively short time

955
00:40:25,489 --> 00:40:29,919

scales that we've seen so the picture

956

00:40:28,250 --> 00:40:33,320

we've come up with for this thing is

957

00:40:29,920 --> 00:40:35,210

that it's a star that near the end of

958

00:40:33,320 --> 00:40:37,309

its life sort of had a book sort of

959

00:40:35,210 --> 00:40:40,340

baked out of a bunch of gas and then

960

00:40:37,309 --> 00:40:42,590

right before the explosion it did this

961

00:40:40,340 --> 00:40:44,240

and then the explosion happens and it

962

00:40:42,590 --> 00:40:47,510

runs into all this material that it's

963

00:40:44,239 --> 00:40:49,250

it's it's burped out that's lit it up so

964

00:40:47,510 --> 00:40:51,110

Kepler is now teaching us things about

965

00:40:49,250 --> 00:40:53,179

exploding stars that we just didn't even

966

00:40:51,110 --> 00:40:55,039

imagine we learn about initially we

967

00:40:53,179 --> 00:40:58,250

never imagined something like this thing

968

00:40:55,039 --> 00:41:00,610

like KSN 20:59 it was just something

969

00:40:58,250 --> 00:41:05,360

that happened to be discovered

970
00:41:00,610 --> 00:41:06,590
fortuitously with this experiment but

971
00:41:05,360 --> 00:41:07,820
now we really want to find the things

972
00:41:06,590 --> 00:41:10,550
that we did imagine right we want to

973
00:41:07,820 --> 00:41:11,960
find the this kind of type 1a supernovae

974
00:41:10,550 --> 00:41:15,500
that I have sort of started this talk

975
00:41:11,960 --> 00:41:17,599
telling you about and Kepler has

976
00:41:15,500 --> 00:41:21,769
effectively broken up at the k2 mission

977
00:41:17,599 --> 00:41:24,440
into several sort of a TDM campaigns the

978
00:41:21,769 --> 00:41:27,139
vast majority of these campaigns the

979
00:41:24,440 --> 00:41:29,179
orientation of Kepler with the earth and

980
00:41:27,139 --> 00:41:31,129
the Sun is exactly how I showed you in

981
00:41:29,179 --> 00:41:33,108
that original movie of it going around

982
00:41:31,130 --> 00:41:36,858
in the same direction just at one of

983
00:41:33,108 --> 00:41:39,048
these fields for campaign 16 and 17 they

984
00:41:36,858 --> 00:41:40,548
did something rather different they

985
00:41:39,048 --> 00:41:43,788
flipped the task up the other direction

986
00:41:40,548 --> 00:41:45,559
that's really useful for us because for

987
00:41:43,789 --> 00:41:47,450
all the other campaigns we've only had a

988
00:41:45,559 --> 00:41:49,940
very short window right around Twilight

989
00:41:47,449 --> 00:41:53,419
where we could see something with the

990
00:41:49,940 --> 00:41:55,068
ground that Kepler could also see but

991
00:41:53,420 --> 00:41:57,588
by flipping the telescope over the other

992
00:41:55,068 --> 00:42:00,619
direction in this lovely cartoon

993
00:41:57,588 --> 00:42:02,119
suddenly the earth and Kepler can both

994
00:42:00,619 --> 00:42:05,079
observe the same patch of sky at the

995
00:42:02,119 --> 00:42:08,059
same time and so here in this beautiful

996
00:42:05,079 --> 00:42:11,180
illustration Kepler says hey give me

997
00:42:08,059 --> 00:42:13,460
some spectra and people on earth us can

998

00:42:11,179 --> 00:42:15,228
go point our spectra this and so for

999
00:42:13,460 --> 00:42:17,139
most of last year we would this is what

1000
00:42:15,228 --> 00:42:20,288
Armand and I and all of the other people

1001
00:42:17,139 --> 00:42:22,879
on this project were involved in hunting

1002
00:42:20,289 --> 00:42:24,829
supernovae the Kepler discovered with

1003
00:42:22,880 --> 00:42:26,690
from the ground seeing if we could get

1004
00:42:24,829 --> 00:42:29,809
more additional information about it and

1005
00:42:26,690 --> 00:42:33,170
realizing what it was soon

1006
00:42:29,809 --> 00:42:34,759
and so campaign 16 and 17 were focused

1007
00:42:33,170 --> 00:42:37,670
on these extra galactic transients and

1008
00:42:34,759 --> 00:42:40,728
it suddenly became like Christmas

1009
00:42:37,670 --> 00:42:44,979
we had been finding you know sakes and

1010
00:42:40,728 --> 00:42:48,018
supernovae we found 42 in campaign 6070

1011
00:42:44,978 --> 00:42:51,439
it's just tremendous explosion of these

1012
00:42:48,018 --> 00:42:53,118

things suddenly a whole bunch more data

1013
00:42:51,440 --> 00:42:55,670
for us to work with lots more papers to

1014
00:42:53,119 --> 00:42:57,619
read lots more analysis to do and so

1015
00:42:55,670 --> 00:42:59,690
what we did was coordinated follow up

1016
00:42:57,619 --> 00:43:02,210
with many many different telescopes the

1017
00:42:59,690 --> 00:43:03,950
pan-starrs telescope in Hawaii the Dec

1018
00:43:02,210 --> 00:43:06,650
cam instrument down in Chile along with

1019
00:43:03,949 --> 00:43:07,778
Swope small telescopes called the atlas

1020
00:43:06,650 --> 00:43:10,759
telescopes that are designed to actually

1021
00:43:07,778 --> 00:43:13,068
provide a warning if an asteroid is

1022
00:43:10,759 --> 00:43:14,690
headed towards Earth a whole bunch of

1023
00:43:13,068 --> 00:43:16,818
different facilities all of these things

1024
00:43:14,690 --> 00:43:18,739
were coordinated observing the same

1025
00:43:16,818 --> 00:43:20,119
patch of sky the Kepler was observing at

1026
00:43:18,739 --> 00:43:22,190
once this is actually kind of

1027
00:43:20,119 --> 00:43:23,630
unprecedented it's hard to get a whole

1028
00:43:22,190 --> 00:43:25,789
bunch of scientists in the same room and

1029
00:43:23,630 --> 00:43:27,650
get them to agree about anything let

1030
00:43:25,789 --> 00:43:30,859
alone do like dedicate the resources to

1031
00:43:27,650 --> 00:43:33,139
what's doing the same science so this is

1032
00:43:30,858 --> 00:43:34,848
really sort of a model for how to manage

1033
00:43:33,139 --> 00:43:38,118
follow-up with scarce resources like

1034
00:43:34,849 --> 00:43:39,920
Hubble in the future and we found

1035
00:43:38,119 --> 00:43:41,778
interesting things so this was one of

1036
00:43:39,920 --> 00:43:44,088
our interesting objects this is

1037
00:43:41,778 --> 00:43:45,679
supernovae 2018 Oh hatch it's a regular

1038
00:43:44,088 --> 00:43:47,480
type 1s soup

1039
00:43:45,679 --> 00:43:49,399
I was covered by the assassin survey on

1040
00:43:47,480 --> 00:43:51,980
the ground and it was in the kepler

1041
00:43:49,400 --> 00:43:54,980
field and here is a image of that

1042
00:43:51,980 --> 00:43:57,289
supernova and if I click this you'll see

1043
00:43:54,980 --> 00:44:00,530
this animation and near the center here

1044
00:43:57,289 --> 00:44:02,599
you should see this thing get brighter

1045
00:44:00,530 --> 00:44:04,040
and brighter over time that's why the

1046
00:44:02,599 --> 00:44:06,710
supernova is that's what Kepler is

1047
00:44:04,039 --> 00:44:08,779
seeing and we can follow it with other

1048
00:44:06,710 --> 00:44:10,490
instruments from the ground and compare

1049
00:44:08,780 --> 00:44:12,829
it with all sorts of other type 1a

1050
00:44:10,489 --> 00:44:15,289
supernovae at the same time and so we

1051
00:44:12,829 --> 00:44:18,318
can finally say hey this thing looks a

1052
00:44:15,289 --> 00:44:20,869
lot like other supernova or desnt we

1053
00:44:18,318 --> 00:44:22,818
can find the differences and we can look

1054
00:44:20,869 --> 00:44:25,250
at these things really early because we

1055

00:44:22,818 --> 00:44:26,929
have this great Kepler light curve so I

1056
00:44:25,250 --> 00:44:29,329
flipped in this great Kepler light curve

1057
00:44:26,929 --> 00:44:31,159
here's you know I sort of four thousand

1058
00:44:29,329 --> 00:44:33,170
observations across the light curve

1059
00:44:31,159 --> 00:44:36,318
those are individual little measurements

1060
00:44:33,170 --> 00:44:38,240
in gray okay every one of those is an

1061
00:44:36,318 --> 00:44:41,029
image Kepler took if we average them

1062
00:44:38,239 --> 00:44:43,250
together in in bins those are the black

1063
00:44:41,030 --> 00:44:45,440
points but the gratings are our actual

1064
00:44:43,250 --> 00:44:47,780
data and this is tremendous because you

1065
00:44:45,440 --> 00:44:50,358
can look at this and look for very very

1066
00:44:47,780 --> 00:44:53,240
minor differences very very many

1067
00:44:50,358 --> 00:44:55,759
departures from theory theory here is

1068
00:44:53,239 --> 00:44:57,529
what the red line is and you can see the

1069
00:44:55,760 --> 00:44:59,569

observations depart just a little bit

1070

00:44:57,530 --> 00:45:02,569
from it but that's the signal that

1071

00:44:59,568 --> 00:45:04,699
really subtle small departure is the

1072

00:45:02,568 --> 00:45:07,308
signal that we're looking for this is

1073

00:45:04,699 --> 00:45:11,269
one of these potential smoking guns so

1074

00:45:07,309 --> 00:45:13,519
that this supernovae is not a simple

1075

00:45:11,269 --> 00:45:15,858
system that you know is simply two white

1076

00:45:13,519 --> 00:45:17,298
dwarfs near each other this looks like

1077

00:45:15,858 --> 00:45:19,818
the sort of excess we'd see if a

1078

00:45:17,298 --> 00:45:23,210
supernova happen when a white dwarf is

1079

00:45:19,818 --> 00:45:24,710
near a star like our Sun and so this is

1080

00:45:23,210 --> 00:45:26,960
starting to look really good because now

1081

00:45:24,710 --> 00:45:30,650
we have clean data that's a lot more

1082

00:45:26,960 --> 00:45:33,170
convincing we can correct a supernova

1083

00:45:30,650 --> 00:45:35,389
compare it against everything else we'd

1084
00:45:33,170 --> 00:45:37,818
seen from Kepler in the past and the

1085
00:45:35,389 --> 00:45:40,400
single slope persists there's just no

1086
00:45:37,818 --> 00:45:42,259
way this flux excess could have been not

1087
00:45:40,400 --> 00:45:43,700
detected in those previous supernovae

1088
00:45:42,260 --> 00:45:45,109
had it been there so this thing is

1089
00:45:43,699 --> 00:45:48,318
genuinely different than the previous

1090
00:45:45,108 --> 00:45:49,818
supernova that even Kepler had seen and

1091
00:45:48,318 --> 00:45:52,519
so the question now is what the source

1092
00:45:49,818 --> 00:45:55,159
of this excess flux is what is the

1093
00:45:52,519 --> 00:45:56,659
physics of the explosion and so we can

1094
00:45:55,159 --> 00:45:58,730
rule out a whole bunch of models but the

1095
00:45:56,659 --> 00:45:59,029
four that remain are collision with a

1096
00:45:58,730 --> 00:46:02,030
binary

1097
00:45:59,030 --> 00:46:05,269
companion star like a son or it could be

1098
00:46:02,030 --> 00:46:06,410
the mixing of nickel which is produced

1099
00:46:05,269 --> 00:46:08,900
during the explosion of a supernova

1100
00:46:06,409 --> 00:46:12,289
right on its surface or it could be

1101
00:46:08,900 --> 00:46:14,240
interaction like you saw in that in that

1102
00:46:12,289 --> 00:46:15,679
book where the star has given off a

1103
00:46:14,239 --> 00:46:18,139
whole bunch of material right before it

1104
00:46:15,679 --> 00:46:20,839
explodes and it's interacting with that

1105
00:46:18,139 --> 00:46:22,639
material lighting it up or it could be

1106
00:46:20,840 --> 00:46:26,000
two of these stars hitting each other

1107
00:46:22,639 --> 00:46:27,769
and blowing Apollo ones and so those are

1108
00:46:26,000 --> 00:46:32,829
the four explanations we were trying to

1109
00:46:27,769 --> 00:46:35,000
sort of consider in the set of papers

1110
00:46:32,829 --> 00:46:37,699
some of the fit the data are better than

1111
00:46:35,000 --> 00:46:39,769
others and so the the two sort of

1112

00:46:37,699 --> 00:46:42,619
leading models right now that we have

1113
00:46:39,769 --> 00:46:45,259
are the circulation model where a

1114
00:46:42,619 --> 00:46:47,389
supernova is running into another main

1115
00:46:45,260 --> 00:46:49,760
sequence star and lighting something up

1116
00:46:47,389 --> 00:46:51,409
or the surface nickel model which we

1117
00:46:49,760 --> 00:46:53,510
can't really rule out with what data we

1118
00:46:51,409 --> 00:46:54,980
have from just Kepler but we have more

1119
00:46:53,510 --> 00:46:56,330
data than just Kepler of course because

1120
00:46:54,980 --> 00:46:59,300
we can follow it up from the ground and

1121
00:46:56,329 --> 00:47:01,039
so we can look for colors and we can

1122
00:46:59,300 --> 00:47:03,289
sort of look and see which models are

1123
00:47:01,039 --> 00:47:05,179
supported and based on this my sort of

1124
00:47:03,289 --> 00:47:06,860
preference here is that this is sort of

1125
00:47:05,179 --> 00:47:09,559
more close to the collision model than

1126
00:47:06,860 --> 00:47:11,420

any of the others there's still some

1127

00:47:09,559 --> 00:47:13,880

debate between the to the surface nickel

1128

00:47:11,420 --> 00:47:15,650

team and the collision team but we've

1129

00:47:13,880 --> 00:47:17,690

narrowed down that grid of possible

1130

00:47:15,650 --> 00:47:20,360

models from several different options to

1131

00:47:17,690 --> 00:47:22,610

do that's a whole lot of improvement

1132

00:47:20,360 --> 00:47:25,820

over what we've had in the past from

1133

00:47:22,610 --> 00:47:27,349

just one object there are other objects

1134

00:47:25,820 --> 00:47:29,930

that we're going to work on soon to you

1135

00:47:27,349 --> 00:47:31,789

this is 2018 agk another supernova that

1136

00:47:29,929 --> 00:47:33,440

we see in this is not perfectly reduced

1137

00:47:31,789 --> 00:47:36,860

yet but it seems to have the same little

1138

00:47:33,440 --> 00:47:40,849

excess of flux down here that we think

1139

00:47:36,860 --> 00:47:42,829

might signify that this too is a star as

1140

00:47:40,849 --> 00:47:45,710

a white dwarf star around a star like

1141
00:47:42,829 --> 00:47:48,349
our Sun that's blowing up and teasing

1142
00:47:45,710 --> 00:47:50,690
out this this really small signature is

1143
00:47:48,349 --> 00:47:52,670
going to be work for the next few months

1144
00:47:50,690 --> 00:47:55,610
for me we're still working on sort of

1145
00:47:52,670 --> 00:47:57,139
removing these these artifacts and

1146
00:47:55,610 --> 00:47:59,390
signatures in the data and some of these

1147
00:47:57,139 --> 00:48:00,769
actually come from how Kepler observes I

1148
00:47:59,389 --> 00:48:03,289
told you we were balancing this thing

1149
00:48:00,769 --> 00:48:05,389
out effectively with sunlight and that

1150
00:48:03,289 --> 00:48:07,670
doesn't work perfectly if you actually

1151
00:48:05,389 --> 00:48:09,440
look at a star with Kepler it bounces

1152
00:48:07,670 --> 00:48:12,139
around because the solar pressure is not

1153
00:48:09,440 --> 00:48:13,039
constant over time and you can see all

1154
00:48:12,139 --> 00:48:14,000
sorts of instrum

1155
00:48:13,039 --> 00:48:15,230
a lot of folks could see a little

1156
00:48:14,000 --> 00:48:17,329
asteroid or something move through the

1157
00:48:15,230 --> 00:48:19,940
frame over here you can see cosmic rays

1158
00:48:17,329 --> 00:48:21,319
all of these complex effects all have to

1159
00:48:19,940 --> 00:48:24,530
be accounted for in the data when we

1160
00:48:21,320 --> 00:48:26,870
analyze things with Kepler but while

1161
00:48:24,530 --> 00:48:29,510
this is a complicated problem teasing

1162
00:48:26,869 --> 00:48:31,339
out these these delicate signals from

1163
00:48:29,510 --> 00:48:32,540
the data is something we can do and

1164
00:48:31,340 --> 00:48:35,180
something we're getting better and

1165
00:48:32,539 --> 00:48:37,429
better with doing but the theories where

1166
00:48:35,179 --> 00:48:39,829
sort of story the happy story sort of

1167
00:48:37,429 --> 00:48:41,690
comes to an end a little bit Kepler is

1168
00:48:39,829 --> 00:48:43,369
dying it's running out of fuel it's on

1169

00:48:41,690 --> 00:48:46,579
its last legs this will almost certainly

1170
00:48:43,369 --> 00:48:48,920
be its last campaign campaign twenty and

1171
00:48:46,579 --> 00:48:50,449
it probably will not finish it they will

1172
00:48:48,920 --> 00:48:52,130
have to probably stop taking

1173
00:48:50,449 --> 00:48:55,639
observations and save the data from the

1174
00:48:52,130 --> 00:48:58,340
telescope before it runs out of fuel but

1175
00:48:55,639 --> 00:49:00,170
the good news is that we have more

1176
00:48:58,340 --> 00:49:03,050
telescopes of the way this is sort of a

1177
00:49:00,170 --> 00:49:04,610
timeline effectively F of NASA's expert

1178
00:49:03,050 --> 00:49:06,980
at Ellis cove and Kepler's over here

1179
00:49:04,610 --> 00:49:09,019
but it's already been succeeded by tests

1180
00:49:06,980 --> 00:49:10,909
just the next great except an admission

1181
00:49:09,019 --> 00:49:12,800
from NASA and it's going to be followed

1182
00:49:10,909 --> 00:49:14,869
by the Webb telescope or model of which

1183
00:49:12,800 --> 00:49:19,280

is over there and in the future sort of

1184

00:49:14,869 --> 00:49:22,579

in 2025 ish w first mission and Tess is

1185

00:49:19,280 --> 00:49:24,019

is an incredible thing where Kepler was

1186

00:49:22,579 --> 00:49:27,289

setting in a small patch of sky at a

1187

00:49:24,019 --> 00:49:30,909

given amount of time into e ups in two

1188

00:49:27,289 --> 00:49:33,829

years tests will cover the entire sky

1189

00:49:30,909 --> 00:49:34,579

we're really high cadence that's pretty

1190

00:49:33,829 --> 00:49:36,920

impressive

1191

00:49:34,579 --> 00:49:38,779

it doesn't go nearly is deepest Kepler

1192

00:49:36,920 --> 00:49:41,750

we can't see as far out into our

1193

00:49:38,780 --> 00:49:43,880

universe as we do but simply because of

1194

00:49:41,750 --> 00:49:46,099

the amount of area it covers at any time

1195

00:49:43,880 --> 00:49:48,410

it will effectively be a machine at

1196

00:49:46,099 --> 00:49:50,299

finding these supernovae and so we'll go

1197

00:49:48,409 --> 00:49:51,619

from probably a handful of objects where

1198
00:49:50,300 --> 00:49:53,720
we can tease out the signal and

1199
00:49:51,619 --> 00:49:56,089
understand the physics of the supernova

1200
00:49:53,719 --> 00:49:57,649
to hundreds of these things and so we

1201
00:49:56,090 --> 00:50:00,380
expect we'll also find things that we've

1202
00:49:57,650 --> 00:50:06,829
just not imagined before in the data and

1203
00:50:00,380 --> 00:50:08,480
that'll be kind of an exciting time so I

1204
00:50:06,829 --> 00:50:10,360
sort of want to wrap things up a little

1205
00:50:08,480 --> 00:50:12,619
bit and take questions from you folks

1206
00:50:10,360 --> 00:50:14,180
Kepler has been a really amazing

1207
00:50:12,619 --> 00:50:16,400
facility for us we've been finding all

1208
00:50:14,179 --> 00:50:18,699
sorts of things that blow up stuff that

1209
00:50:16,400 --> 00:50:21,230
effectively made me an astronomer and

1210
00:50:18,699 --> 00:50:24,439
lit up my eyes as a kid all of these

1211
00:50:21,230 --> 00:50:27,050
exciting explosions we've seen these

1212
00:50:24,440 --> 00:50:28,880
excess flux in a couple of objects

1213
00:50:27,050 --> 00:50:30,260
we've seen other objects that don't have

1214
00:50:28,880 --> 00:50:32,809
it we have seen things that we just

1215
00:50:30,260 --> 00:50:35,390
didn't imagine this for example is a

1216
00:50:32,809 --> 00:50:38,000
light curve for an object my student is

1217
00:50:35,389 --> 00:50:40,279
working on and it's entire time scale is

1218
00:50:38,000 --> 00:50:42,260
about 20 days it rises and falls much

1219
00:50:40,280 --> 00:50:44,119
much faster than the supernovae and we

1220
00:50:42,260 --> 00:50:46,310
know nothing like it we've never seen

1221
00:50:44,119 --> 00:50:49,250
anything that behaves like this it's

1222
00:50:46,309 --> 00:50:51,108
just a mystery as to what it is that's

1223
00:50:49,250 --> 00:50:53,420
just cool its discovery space for us

1224
00:50:51,108 --> 00:50:55,159
well we're learning about explosions

1225
00:50:53,420 --> 00:50:56,780
that Kepler himself could never have

1226

00:50:55,159 --> 00:51:01,608
imagined but these things are so rare

1227
00:50:56,780 --> 00:51:02,750
that he never would have seen them and

1228
00:51:01,608 --> 00:51:05,690
we're finding things earlier and earlier

1229
00:51:02,750 --> 00:51:07,789
than we've ever managed to before along

1230
00:51:05,690 --> 00:51:09,769
with experiments like Lego which

1231
00:51:07,789 --> 00:51:12,050
understand not just photons but

1232
00:51:09,769 --> 00:51:14,539
gravitational waves and ice cubes that

1233
00:51:12,050 --> 00:51:16,789
are studying neutrinos we're really

1234
00:51:14,539 --> 00:51:18,949
learning about things across the entire

1235
00:51:16,789 --> 00:51:20,539
electromagnetic spectrum we're no longer

1236
00:51:18,949 --> 00:51:22,639
just looking at the sort of beautiful

1237
00:51:20,539 --> 00:51:25,300
visible light images like this Hubble

1238
00:51:22,639 --> 00:51:29,750
picture you got of the bubble nebula

1239
00:51:25,300 --> 00:51:32,030
right when you walk in and this is

1240
00:51:29,750 --> 00:51:33,619

really cool because what will happen is

1241

00:51:32,030 --> 00:51:36,890

that will understand the progenitor

1242

00:51:33,619 --> 00:51:38,210

systems and physics of these supernovae

1243

00:51:36,889 --> 00:51:40,819

which will in turn help us understand

1244

00:51:38,210 --> 00:51:42,980

and explain and improve our models of

1245

00:51:40,820 --> 00:51:45,650

supernovae better and so in a few years

1246

00:51:42,980 --> 00:51:48,260

if you come back here I hope to not have

1247

00:51:45,650 --> 00:51:50,180

any of these question marks on our

1248

00:51:48,260 --> 00:51:53,030

slides anymore I hope to not have any

1249

00:51:50,179 --> 00:51:55,159

circles where we don't understand what

1250

00:51:53,030 --> 00:51:57,710

the origin of a particular stars

1251

00:51:55,159 --> 00:51:59,960

explosion is I hope we'll be able to

1252

00:51:57,710 --> 00:52:02,358

fill that entire thing out and tell you

1253

00:51:59,960 --> 00:52:04,849

here is how this star lived here is how

1254

00:52:02,358 --> 00:52:06,699

the star died and there's more to come

1255
00:52:04,849 --> 00:52:09,289
because there's so many more exciting

1256
00:52:06,699 --> 00:52:11,509
missions in the near future and without

1257
00:52:09,289 --> 00:52:18,909
a questions

1258
00:52:11,510 --> 00:52:18,909
[Applause]

1259
00:52:21,079 --> 00:52:28,529
all right can we have the microphone

1260
00:52:25,590 --> 00:52:30,809
cube coming down yes the microphone cube

1261
00:52:28,530 --> 00:52:33,330
is coming down all right who's got a

1262
00:52:30,809 --> 00:52:43,829
question for us you can do it without

1263
00:52:33,329 --> 00:52:46,139
the microphone cube I'll repeat it when

1264
00:52:43,829 --> 00:52:55,349
these supernovas blow up what happens

1265
00:52:46,139 --> 00:52:58,289
after that you know in the stream it

1266
00:52:55,349 --> 00:53:01,349
just dissipates what happens this is a

1267
00:52:58,289 --> 00:53:03,389
beautiful question so if you look at

1268
00:53:01,349 --> 00:53:05,369
that image of the bubble nebula that you

1269
00:53:03,389 --> 00:53:07,949
got as you walked in that's hot what

1270
00:53:05,369 --> 00:53:09,239
that's what remains from a supernova

1271
00:53:07,949 --> 00:53:12,689
Ashley can you put me one of those

1272
00:53:09,239 --> 00:53:14,839
things up one of these this is kind of

1273
00:53:12,690 --> 00:53:17,460
what it looks like for a supernova

1274
00:53:14,840 --> 00:53:19,769
several hundreds of years after the

1275
00:53:17,460 --> 00:53:22,500
explosions happened and so what you have

1276
00:53:19,769 --> 00:53:24,150
is this smorgasbord of material that was

1277
00:53:22,500 --> 00:53:26,489
produced in the explosion of the stars

1278
00:53:24,150 --> 00:53:29,369
all the heavy elements all the way up to

1279
00:53:26,489 --> 00:53:30,750
iron on the periodic table and it's it's

1280
00:53:29,369 --> 00:53:32,670
absolutely true that supernovae are

1281
00:53:30,750 --> 00:53:34,949
destructive forces if there are planets

1282
00:53:32,670 --> 00:53:37,590
around that curve and it blew up they

1283

00:53:34,949 --> 00:53:39,210
aren't there anymore but on the other

1284
00:53:37,590 --> 00:53:40,860
hand they are also creative forces

1285
00:53:39,210 --> 00:53:43,440
because these things are effectively

1286
00:53:40,860 --> 00:53:45,660
engines producing the periodic table

1287
00:53:43,440 --> 00:53:47,579
you're absolutely right they enrich the

1288
00:53:45,659 --> 00:53:49,920
galaxies they enrich the surrounding

1289
00:53:47,579 --> 00:53:52,019
environment the next generation of stars

1290
00:53:49,920 --> 00:53:53,760
that will be formed would be from it

1291
00:53:52,019 --> 00:53:56,670
will incorporate material from the

1292
00:53:53,760 --> 00:53:59,070
supernova they will have more metal for

1293
00:53:56,670 --> 00:54:01,500
example and stars like our Sun which I

1294
00:53:59,070 --> 00:54:03,300
could post mostly of hydrogen have

1295
00:54:01,500 --> 00:54:04,980
slightly different properties and this

1296
00:54:03,300 --> 00:54:11,940
is effectively the universe recycling a

1297
00:54:04,980 --> 00:54:15,019

little bit that's what the wife of the

1298

00:54:11,940 --> 00:54:15,019
speaker asked her question

1299

00:54:20,489 --> 00:54:25,389
not about the type of the explosion our

1300

00:54:22,780 --> 00:54:27,670
son will have so star like that son is

1301

00:54:25,389 --> 00:54:29,710
not going to have an explosive fiery

1302

00:54:27,670 --> 00:54:32,530
death it's it's a little bit more wimpy

1303

00:54:29,710 --> 00:54:36,099
it's going to sort of puff up and become

1304

00:54:32,530 --> 00:54:38,019
a red giant star its size will be a

1305

00:54:36,099 --> 00:54:40,659
little less than the orbit of Jupiter so

1306

00:54:38,019 --> 00:54:41,949
all the inner planets will be cooked but

1307

00:54:40,659 --> 00:54:43,179
this will be in about five billion years

1308

00:54:41,949 --> 00:54:50,769
you don't worry about your property

1309

00:54:43,179 --> 00:54:53,259
values and once that that puffy red

1310

00:54:50,769 --> 00:54:56,170
giant phase is over what's left at the

1311

00:54:53,260 --> 00:54:57,490
center of the star is its core this

1312
00:54:56,170 --> 00:55:00,039
white dwarf the sort of thing that

1313
00:54:57,489 --> 00:55:03,279
becomes a supernova of type 1a

1314
00:55:00,039 --> 00:55:05,679
potentially that white dwarf if nothing

1315
00:55:03,280 --> 00:55:07,930
happens to it if it sits there by itself

1316
00:55:05,679 --> 00:55:10,179
it will simply cool for the rest of the

1317
00:55:07,929 --> 00:55:11,799
lifetime of the universe what when

1318
00:55:10,179 --> 00:55:14,710
interesting things happen is when that

1319
00:55:11,800 --> 00:55:18,330
white dwarf starts to get mass from some

1320
00:55:14,710 --> 00:55:20,769
other companion whether another star or

1321
00:55:18,329 --> 00:55:21,759
another white wolf and that's exactly

1322
00:55:20,769 --> 00:55:26,829
the kind of scenario we're trying to

1323
00:55:21,760 --> 00:55:30,370
figure out hey other questions yes in

1324
00:55:26,829 --> 00:55:32,920
the center there catch that's the

1325
00:55:30,369 --> 00:55:35,199
microphone there 18 and 17 you pointed

1326
00:55:32,920 --> 00:55:38,829
the Kepler the other direction and

1327
00:55:35,199 --> 00:55:42,369
coordinated with earth and I don't know

1328
00:55:38,829 --> 00:55:44,019
seven or eight more times observations

1329
00:55:42,369 --> 00:55:45,400
in supernovae is that because of the

1330
00:55:44,019 --> 00:55:46,719
coordination with the earth or because

1331
00:55:45,400 --> 00:55:52,000
it was pointing the other way well

1332
00:55:46,719 --> 00:55:53,500
exactly so so the question was that did

1333
00:55:52,000 --> 00:55:54,789
we find more of these supernovae because

1334
00:55:53,500 --> 00:55:55,329
we were pointing the telescope in the

1335
00:55:54,789 --> 00:55:57,929
other direction

1336
00:55:55,329 --> 00:56:00,250
the answer is exactly yes when it's

1337
00:55:57,929 --> 00:56:02,259
forward-facing in the configuration I

1338
00:56:00,250 --> 00:56:04,750
showed you there's only a short window

1339
00:56:02,260 --> 00:56:07,560
around Twilight morning and evening

1340

00:56:04,750 --> 00:56:09,940
Twilight when observers on the ground

1341
00:56:07,559 --> 00:56:12,460
can look at the same area of the sky the

1342
00:56:09,940 --> 00:56:14,409
Kepler is looking after that the field

1343
00:56:12,460 --> 00:56:16,240
sets and so it's below the horizon

1344
00:56:14,409 --> 00:56:18,609
we can't go point our telescopes at it

1345
00:56:16,239 --> 00:56:20,439
at night that doesn't make for a very

1346
00:56:18,610 --> 00:56:22,480
large window with which to go find

1347
00:56:20,440 --> 00:56:25,570
supernovae when you do it in the

1348
00:56:22,480 --> 00:56:28,059
opposite geometry then suddenly the

1349
00:56:25,570 --> 00:56:30,190
field that Kepler is pointing at is also

1350
00:56:28,059 --> 00:56:31,750
available to be observed from the ground

1351
00:56:30,190 --> 00:56:34,659
for basically the entire

1352
00:56:31,750 --> 00:56:39,280
it's dark and because we have more time

1353
00:56:34,659 --> 00:56:40,389
to find things we find more things all

1354
00:56:39,280 --> 00:56:44,710

right we've got a question from online

1355

00:56:40,389 --> 00:56:46,449

I'm gonna ask it says is there any

1356

00:56:44,710 --> 00:56:49,358

neutrino emission from a supernova

1357

00:56:46,449 --> 00:56:52,960

explosion oh that is an interesting and

1358

00:56:49,358 --> 00:56:56,489

research question so the answer is there

1359

00:56:52,960 --> 00:56:59,889

has been we know of at least one object

1360

00:56:56,489 --> 00:57:02,679

supernova 1987a in Large Magellanic

1361

00:56:59,889 --> 00:57:05,440

Cloud that emitted some neutrinos they

1362

00:57:02,679 --> 00:57:06,669

have to be very powerful explosions the

1363

00:57:05,440 --> 00:57:09,760

kind of explosions that create these

1364

00:57:06,670 --> 00:57:11,530

neutrinos are almost certainly that not

1365

00:57:09,760 --> 00:57:14,140

the type 1a supernova I was looking at

1366

00:57:11,530 --> 00:57:15,609

but much more analogous to the collapse

1367

00:57:14,139 --> 00:57:18,598

of those massive stars like Krypton

1368

00:57:15,608 --> 00:57:21,460

exploding the Sun of Krypton exploding

1369
00:57:18,599 --> 00:57:23,769
those sort of events will produce entry

1370
00:57:21,460 --> 00:57:25,568
knows there's a lot of research to try

1371
00:57:23,769 --> 00:57:28,780
to find these things that are detectors

1372
00:57:25,568 --> 00:57:30,969
that are essentially giant rats of heavy

1373
00:57:28,780 --> 00:57:33,730
water and sodium with photomultiplier

1374
00:57:30,969 --> 00:57:35,828
tubes all around them both in Antarctica

1375
00:57:33,730 --> 00:57:37,510
and Japan all over the place to try to

1376
00:57:35,829 --> 00:57:39,369
find these signals but we've not been

1377
00:57:37,510 --> 00:57:42,490
able to find very many of these things

1378
00:57:39,369 --> 00:57:43,900
they're really hard to tease out because

1379
00:57:42,489 --> 00:57:47,769
we also just don't find that many

1380
00:57:43,900 --> 00:57:57,880
supernovae near us it's probably for the

1381
00:57:47,769 --> 00:57:59,440
best really given the age of the

1382
00:57:57,880 --> 00:58:02,920
universe something thirteen or fourteen

1383
00:57:59,440 --> 00:58:06,940
billion years are there likely to be

1384
00:58:02,920 --> 00:58:10,780
more supernovae in the future or is the

1385
00:58:06,940 --> 00:58:12,429
kind of steady state this is a beautiful

1386
00:58:10,780 --> 00:58:14,829
question that's and that has a

1387
00:58:12,429 --> 00:58:17,649
complicated answer they're the kinds of

1388
00:58:14,829 --> 00:58:20,890
supernovae and rates change as a

1389
00:58:17,650 --> 00:58:23,079
function of the age of the universe so

1390
00:58:20,889 --> 00:58:26,170
as we go further and further back in

1391
00:58:23,079 --> 00:58:27,519
time you expect fewer and fewer type 1a

1392
00:58:26,170 --> 00:58:31,030
supernovae the universe hasn't had

1393
00:58:27,519 --> 00:58:33,639
enough time for stars to grow or die

1394
00:58:31,030 --> 00:58:35,710
form white dwarfs and have like many

1395
00:58:33,639 --> 00:58:38,139
type 1a supernovae but on the other hand

1396
00:58:35,710 --> 00:58:40,449
you have more and more massive stars the

1397

00:58:38,139 --> 00:58:42,009
further back in time you look and so you

1398
00:58:40,449 --> 00:58:45,048
have more core collapse explosions

1399
00:58:42,010 --> 00:58:46,579
moving this far

1400
00:58:45,048 --> 00:58:48,829
into the future the opposite thing

1401
00:58:46,579 --> 00:58:50,480
happens you will expect more type 1a

1402
00:58:48,829 --> 00:58:52,539
supernovae because the universe is older

1403
00:58:50,480 --> 00:58:55,849
and you have more of these white walls

1404
00:58:52,539 --> 00:58:57,170
but and you'll expect fewer collapse

1405
00:58:55,849 --> 00:58:59,509
explosions because the universe is just

1406
00:58:57,170 --> 00:59:03,528
producing less of these really massive

1407
00:58:59,509 --> 00:59:05,358
stars but we're talking about changes

1408
00:59:03,528 --> 00:59:07,248
over billions of years these are hard to

1409
00:59:05,358 --> 00:59:09,440
measure on sort of small time scales

1410
00:59:07,248 --> 00:59:10,879
like millions of years so it is really

1411
00:59:09,440 --> 00:59:12,108

very far in the future we're talking

1412

00:59:10,880 --> 00:59:14,599

about where we will see a significant

1413

00:59:12,108 --> 00:59:16,159

difference the the numbers of these

1414

00:59:14,599 --> 00:59:17,869

things that we find are actually quite

1415

00:59:16,159 --> 00:59:21,108

uncertain and so these this is an active

1416

00:59:17,869 --> 00:59:23,420

area of study okay let's get the

1417

00:59:21,108 --> 00:59:26,358

microphone up there I um I was wondering

1418

00:59:23,420 --> 00:59:27,680

uh do we have any predictive ways of

1419

00:59:26,358 --> 00:59:29,509

figuring out whether a particular star

1420

00:59:27,679 --> 00:59:31,098

is going supernova I mean obviously

1421

00:59:29,509 --> 00:59:33,469

maybe we can be like oh yeah and a

1422

00:59:31,099 --> 00:59:37,068

couple million years but anything within

1423

00:59:33,469 --> 00:59:38,028

our lifetimes so sorry and I also wanted

1424

00:59:37,068 --> 00:59:40,308

to ask what would happen if the

1425

00:59:38,028 --> 00:59:44,630

supernova did happen near us like Alpha

1426
00:59:40,309 --> 00:59:46,640
Centauri or something all right so all

1427
00:59:44,630 --> 00:59:49,519
our particular ways of looking for

1428
00:59:46,639 --> 00:59:52,190
supernova events in some cases yeah we

1429
00:59:49,518 --> 00:59:55,219
sort of if you look up in in the night

1430
00:59:52,190 --> 00:59:57,139
sky today and you go look at the Orion

1431
00:59:55,219 --> 00:59:59,568
constellation you'll see a style called

1432
00:59:57,139 --> 01:00:02,629
beatlejuice beatlejuice is a red giant

1433
00:59:59,568 --> 01:00:04,068
star it'll die in its in some point of

1434
01:00:02,630 --> 01:00:06,710
time for the other we know it'll extend

1435
01:00:04,068 --> 01:00:09,798
its life as a supernova the problem is

1436
01:00:06,710 --> 01:00:11,599
we just don't know when that will be it

1437
01:00:09,798 --> 01:00:12,949
might be a million years it might be

1438
01:00:11,599 --> 01:00:15,680
tomorrow it might be several billion

1439
01:00:12,949 --> 01:00:17,028
years this is a problem if you sort of

1440
01:00:15,679 --> 01:00:18,528
want to write your PhD thesis because

1441
01:00:17,028 --> 01:00:18,829
you only have a few of these years to do

1442
01:00:18,528 --> 01:00:23,179
it

1443
01:00:18,829 --> 01:00:24,859
and similarly people have looked for

1444
01:00:23,179 --> 01:00:26,989
sort of white dwarfs which are around

1445
01:00:24,858 --> 01:00:28,818
other systems and look to be sort of in

1446
01:00:26,989 --> 01:00:30,380
decaying orbits where they look like

1447
01:00:28,818 --> 01:00:31,608
they might merge and have an explosion

1448
01:00:30,380 --> 01:00:35,180
but none of these systems are sort of

1449
01:00:31,608 --> 01:00:37,630
easily study about on timescales that

1450
01:00:35,179 --> 01:00:39,649
are comparable to human lifetimes so

1451
01:00:37,630 --> 01:00:41,930
what we do is the scattershot approach

1452
01:00:39,650 --> 01:00:44,239
where instead we look in lots and lots

1453
01:00:41,929 --> 01:00:47,028
of millions of galaxies and try to find

1454

01:00:44,239 --> 01:00:50,210
what blew up instead as for what will

1455
01:00:47,028 --> 01:00:52,338
happen if Alpha Centauri blew up near us

1456
01:00:50,210 --> 01:00:52,880
not whole lot it's actually pretty far

1457
01:00:52,338 --> 01:00:54,798
away

1458
01:00:52,880 --> 01:00:57,650
so Proxima Centuri is is about four

1459
01:00:54,798 --> 01:00:58,969
ideas away we you

1460
01:00:57,650 --> 01:01:00,318
really worrying about and you'd see

1461
01:00:58,969 --> 01:01:02,989
something cool in the night sky for a

1462
01:01:00,318 --> 01:01:08,000
while but it's far enough away that it's

1463
01:01:02,989 --> 01:01:10,608
not a huge impact anytime soon you

1464
01:01:08,000 --> 01:01:12,980
mentioned the subject of neutrinos came

1465
01:01:10,608 --> 01:01:16,038
up is that the reference to ice cube up

1466
01:01:12,980 --> 01:01:18,108
there yep so the ice cube experiment is

1467
01:01:16,039 --> 01:01:19,869
has a whole bunch of people at the

1468
01:01:18,108 --> 01:01:23,150

University of Maryland involved in it

1469

01:01:19,869 --> 01:01:25,910

and so we're really excited about these

1470

01:01:23,150 --> 01:01:27,440

things because they're really a channel

1471

01:01:25,909 --> 01:01:29,528

of physics that we've not been able to

1472

01:01:27,440 --> 01:01:32,778

probe easily in the past we've had

1473

01:01:29,528 --> 01:01:35,119

telescopes like Hubble and JWST in the

1474

01:01:32,778 --> 01:01:36,980

future that look at photons but

1475

01:01:35,119 --> 01:01:39,500

neutrinos are effectively giving us a

1476

01:01:36,980 --> 01:01:41,028

different story of physics and so we're

1477

01:01:39,500 --> 01:01:43,699

really excited about what we can learn

1478

01:01:41,028 --> 01:01:48,079

as these facilities like ice cube get

1479

01:01:43,699 --> 01:01:49,399

more and more sophisticated so we've got

1480

01:01:48,079 --> 01:01:52,278

a question on line I'm trying to

1481

01:01:49,400 --> 01:01:55,369

paraphrase it can we measure a star's

1482

01:01:52,278 --> 01:02:00,588

rate of decay into a white dwarf or its

1483
01:01:55,369 --> 01:02:01,940
transition from stable to unstable can

1484
01:02:00,588 --> 01:02:04,578
we measure the spin looked at if we

1485
01:02:01,940 --> 01:02:06,019
looked at you know the sun's gonna go

1486
01:02:04,579 --> 01:02:09,619
white dwarf in you know five billion

1487
01:02:06,019 --> 01:02:13,639
years right now or even measures if it's

1488
01:02:09,619 --> 01:02:18,099
gonna go we think we've seen stars

1489
01:02:13,639 --> 01:02:21,199
evolve significantly in a very few cases

1490
01:02:18,099 --> 01:02:24,079
there are stars that are already in a

1491
01:02:21,199 --> 01:02:27,828
part of space called the instability

1492
01:02:24,079 --> 01:02:32,359
scrip scrip and these stars effectively

1493
01:02:27,829 --> 01:02:36,278
are sort of done burning fuel for the

1494
01:02:32,358 --> 01:02:38,960
most part they're slowly moving towards

1495
01:02:36,278 --> 01:02:40,730
these other phases of stellar level you

1496
01:02:38,960 --> 01:02:44,298
shouldn't be the red giant or a white

1497
01:02:40,730 --> 01:02:47,150
dwarf and and because these things are

1498
01:02:44,298 --> 01:02:49,038
stable they do show pulsations over time

1499
01:02:47,150 --> 01:02:51,710
they show all sorts of unpredictable

1500
01:02:49,039 --> 01:02:54,528
behavior and so that kind of thing has

1501
01:02:51,710 --> 01:02:58,130
been studied but have we seen a single

1502
01:02:54,528 --> 01:03:01,039
star evolve from burning hydrogen to

1503
01:02:58,130 --> 01:03:02,568
running out of fuel becoming a red giant

1504
01:03:01,039 --> 01:03:05,390
and then becoming a way to offer and oh

1505
01:03:02,568 --> 01:03:07,788
that that would be several billion years

1506
01:03:05,389 --> 01:03:09,588
all right we see the most massive stars

1507
01:03:07,789 --> 01:03:11,370
like in a car right you know over the

1508
01:03:09,588 --> 01:03:13,769
past 150 years it's had lots

1509
01:03:11,369 --> 01:03:16,650
per site and such so the very massive

1510
01:03:13,769 --> 01:03:20,449
stars we see things but that the boring

1511

01:03:16,650 --> 01:03:20,450
stars are kind of boring yeah right

1512
01:03:21,860 --> 01:03:26,630
other questions here I'm going up there

1513
01:03:29,150 --> 01:03:36,900
cool what kind of things can you predict

1514
01:03:34,829 --> 01:03:40,319
about stars as the metallicity of the

1515
01:03:36,900 --> 01:03:42,329
stars increase and so you start ending

1516
01:03:40,320 --> 01:03:44,340
up with very massive stars that are

1517
01:03:42,329 --> 01:03:46,049
going to go supernova but they've got a

1518
01:03:44,340 --> 01:03:50,160
lot more metal than the stars in the

1519
01:03:46,050 --> 01:03:51,150
current era do so we this is a hard

1520
01:03:50,159 --> 01:03:55,079
question without getting a whole bunch

1521
01:03:51,150 --> 01:03:56,519
of stellar astrophysics maybe the right

1522
01:03:55,079 --> 01:03:58,409
answer to this question is that I find

1523
01:03:56,519 --> 01:04:02,159
you after this talk and we shot because

1524
01:03:58,409 --> 01:04:04,949
this is lots of properties of stars

1525
01:04:02,159 --> 01:04:06,989

change the temperature surface

1526

01:04:04,949 --> 01:04:08,699

properties sort of whether they have

1527

01:04:06,989 --> 01:04:10,229

sunspots or not there's so many

1528

01:04:08,699 --> 01:04:12,750

different properties of stars are

1529

01:04:10,230 --> 01:04:14,250

effectively a impacted by whether they

1530

01:04:12,750 --> 01:04:16,320

have just a small amount of metal in

1531

01:04:14,250 --> 01:04:18,630

them and so as the metallicity of stars

1532

01:04:16,320 --> 01:04:20,430

changed lots of different things change

1533

01:04:18,630 --> 01:04:24,059

at the same time and it's a really

1534

01:04:20,429 --> 01:04:26,069

complicated picture to try to explain

1535

01:04:24,059 --> 01:04:28,019

all of that but you know the answer is

1536

01:04:26,070 --> 01:04:31,340

we see these things we see it has an

1537

01:04:28,019 --> 01:04:31,340

impact which is why we care about it

1538

01:04:35,840 --> 01:04:42,930

so you said that the supernovae are the

1539

01:04:39,630 --> 01:04:45,720

source of many the minerals in the

1540
01:04:42,929 --> 01:04:49,559
universe and the earth is made of these

1541
01:04:45,719 --> 01:04:52,919
elements so do we have any guess when

1542
01:04:49,559 --> 01:04:54,750
and where from the elements that where

1543
01:04:52,920 --> 01:04:58,110
the supernova was that produced the

1544
01:04:54,750 --> 01:04:59,460
elements that comprise the earth not not

1545
01:04:58,110 --> 01:05:03,840
a good guess at all all right

1546
01:04:59,460 --> 01:05:06,510
the the our galaxy our solar system is

1547
01:05:03,840 --> 01:05:08,840
is several billion years old

1548
01:05:06,510 --> 01:05:10,890
the earth is about 4.3 billion years old

1549
01:05:08,840 --> 01:05:12,420
supernovae that would have gone off in

1550
01:05:10,889 --> 01:05:14,009
our galaxy before that we obviously

1551
01:05:12,420 --> 01:05:15,900
can't study and tell you anything about

1552
01:05:14,010 --> 01:05:18,540
but they'd have had to happen before

1553
01:05:15,900 --> 01:05:21,210
that for all of these metals to be

1554
01:05:18,539 --> 01:05:24,360
around now they get the Galaxy itself

1555
01:05:21,210 --> 01:05:26,309
has a dynamical time scale it involves

1556
01:05:24,360 --> 01:05:28,590
changes stars move around and that

1557
01:05:26,309 --> 01:05:30,269
timescales much shorter so there's

1558
01:05:28,590 --> 01:05:32,760
almost no way to back back out

1559
01:05:30,269 --> 01:05:35,460
effectively what star exploded as a

1560
01:05:32,760 --> 01:05:38,070
supernova to effectively seed the earth

1561
01:05:35,460 --> 01:05:39,869
with its it's primordial elements we

1562
01:05:38,070 --> 01:05:41,460
can't ever tell that in fact the last

1563
01:05:39,869 --> 01:05:44,519
supernova we've seen in our galaxy with

1564
01:05:41,460 --> 01:05:45,929
our that was visibly observed in in the

1565
01:05:44,519 --> 01:05:52,349
northern hemisphere was in fact Kepler

1566
01:05:45,929 --> 01:05:54,419
supernova 16 in 1609 yeah and they a

1567
01:05:52,349 --> 01:05:56,279
good thing that keep in mind is our Sun

1568

01:05:54,420 --> 01:05:58,440
has made about eighteen orbits around

1569
01:05:56,280 --> 01:06:00,990
the center of the Milky Way since it was

1570
01:05:58,440 --> 01:06:03,720
born so there's a lot of diffusion and

1571
01:06:00,989 --> 01:06:07,079
things that happens in 18 orbits and so

1572
01:06:03,719 --> 01:06:09,659
the what-what was near us 18 orbits ago

1573
01:06:07,079 --> 01:06:11,400
is not necessarily near us today and of

1574
01:06:09,659 --> 01:06:13,529
course the Galaxy itself is a violent

1575
01:06:11,400 --> 01:06:15,090
place on our Milky Way we've seen

1576
01:06:13,530 --> 01:06:16,980
evidence of it cannibalizing other

1577
01:06:15,090 --> 01:06:18,869
galaxies there's a stream of stars

1578
01:06:16,980 --> 01:06:20,670
called the Sagittarius stream which we

1579
01:06:18,869 --> 01:06:22,590
think is effectively the Milky Way

1580
01:06:20,670 --> 01:06:25,200
eating the stars off of another galaxy

1581
01:06:22,590 --> 01:06:27,150
but a big matter off of it into our own

1582
01:06:25,199 --> 01:06:29,189

and this will eventually happen several

1583

01:06:27,150 --> 01:06:31,230

billions of years into the future with

1584

01:06:29,190 --> 01:06:34,050

our galaxy and Andromeda these things

1585

01:06:31,230 --> 01:06:35,730

will come to a head and and there will

1586

01:06:34,050 --> 01:06:38,609

be stars effectively moving between

1587

01:06:35,730 --> 01:06:40,469

these two galaxies so these systems are

1588

01:06:38,608 --> 01:06:43,380

unstable and we wish we could trace

1589

01:06:40,469 --> 01:06:44,819

things back that far but okay we've got

1590

01:06:43,380 --> 01:06:45,990

a couple kids up in the corner I told

1591

01:06:44,820 --> 01:06:47,309

them they can have a question if they

1592

01:06:45,989 --> 01:06:49,368

have to have it do you have any

1593

01:06:47,309 --> 01:06:54,268

questions for us tonight

1594

01:06:49,369 --> 01:06:56,460

all right I always like you know when we

1595

01:06:54,268 --> 01:06:58,348

get dusk school kids coming I always

1596

01:06:56,460 --> 01:07:02,579

like to answer their questions all right

1597
01:06:58,349 --> 01:07:05,338
next month November 13 the week after

1598
01:07:02,579 --> 01:07:06,960
election day Bill Blair will be talking

1599
01:07:05,338 --> 01:07:09,150
about observing with Hubble the whole

1600
01:07:06,960 --> 01:07:11,608
process from the idea through these

1601
01:07:09,150 --> 01:07:13,528
proposals all the way up to getting your

1602
01:07:11,608 --> 01:07:15,538
data processing it and polishing the

1603
01:07:13,528 --> 01:07:16,739
paper okay observing with Hubble Bill

1604
01:07:15,539 --> 01:07:19,789
Blair November 13th

1605
01:07:16,739 --> 01:07:19,788
let us gift