PUBLIC LECTURE SERIES

Chasing Supernovae with Kepler

Featuring Guest Speaker:
Gautham Narayan

1
00:00:04,070 --> 00:00:01,429
good evening ladies and gentlemen and

2
00:00:06,619 --> 00:00:04,080
welcome to the Space Telescope public

3
00:00:08,179 --> 00:00:06,629
lecture series I'm your host dr. Frank

4
00:00:11,030 --> 00:00:08,189
summers of the office of public outreach

5
00:00:14,209 --> 00:00:11,040
and it is my pleasure to welcome you

6
00:00:16,540 --> 00:00:14,219
here as you came in you might have

7
00:00:19,310 --> 00:00:16,550
picked up one of our lithographs

8
00:00:22,189 --> 00:00:19,320
tonight's lithograph is a supernova

9
00:00:24,320 --> 00:00:22,199
remnant a the remnant of a explosion of

10
00:00:26,210 --> 00:00:24,330
a star looks like a nice red bubble

11
00:00:29,689 --> 00:00:26,220
matter of fact its nickname is the red

12
00:00:31,400 --> 00:00:29,699
bubble its supernova remnant Oh 509 and

13
00:00:34,069 --> 00:00:31,410

I think there's actually more than two

14
00:00:35,209 --> 00:00:34,079
the name of it but anyways if you would

15
00:00:37,819 --> 00:00:35,219
like to know more about it

16
00:00:39,889 --> 00:00:37,829
turn over on the back and read the text

17
00:00:43,400 --> 00:00:39,899
there that our office public outreach

18
00:00:44,750 --> 00:00:43,410
has put there for you our speaker

19
00:00:47,959 --> 00:00:44,760
tonight we'll be talking about

20
00:00:52,069 --> 00:00:47,969
supernovae chasing supernovae with

21
00:00:54,590 --> 00:00:52,079
Kepler marvelous repurposing of a

22
00:00:56,119 --> 00:00:54,600
satellite to do all sorts of science

23
00:00:58,869 --> 00:00:56,129
it's really kind of cool decay to all

24
00:01:01,970 --> 00:00:58,879
the all the different k2 mission

25
00:01:04,939 --> 00:01:01,980
upcoming now this has changed okay

26
00:01:07,160 --> 00:01:04,949
I had a cancellation and I refilled it

27
00:01:09,950 --> 00:01:07,170
and I've gotten new stuff here so on

28
00:01:13,340 --> 00:01:09,960
November which is the second Tuesday the

29
00:01:15,950 --> 00:01:13,350
first Tuesday is election day so go vote

30
00:01:18,679 --> 00:01:15,960
don't come here go vote and on the

31
00:01:21,289 --> 00:01:18,689
second Tuesday whether your party wins

32
00:01:23,899 --> 00:01:21,299
or loses come here and learn about

33
00:01:26,929 --> 00:01:23,909
observing with Hubble from scientific

34
00:01:30,520 --> 00:01:26,939
idea to published result and everything

35
00:01:32,899 --> 00:01:30,530
in between okay Bill Blair said it has a

36
00:01:35,690 --> 00:01:32,909
he's been having a lot of fun preparing

37
00:01:37,460 --> 00:01:35,700
this talk and if he did really

38
00:01:41,600 --> 00:01:37,470

everything in between it'd probably be a

39
00:01:44,600 --> 00:01:41,610
17-month talk so I think he'll condense

40
00:01:47,480 --> 00:01:44,610
it just a little bit for us in December

41
00:01:50,840 --> 00:01:47,490
Mark kamionkowski has volunteered to do

42
00:01:55,100 --> 00:01:50,850
his talk on black holes and other dark

43
00:01:57,859 --> 00:01:55,110
matters two of the most popular topics

44
00:02:01,940 --> 00:01:57,869
in astronomy you won't want to miss this

45
00:02:04,429 --> 00:02:01,950
one and in January note it's the third

46
00:02:06,410 --> 00:02:04,439
Tuesday the first Tuesday is New Year's

47
00:02:09,199 --> 00:02:06,420
Day so we're not going to do it then the

48
00:02:11,089 --> 00:02:09,209
second Tuesday happens during the

49
00:02:13,600 --> 00:02:11,099
American Astronomical Society meeting

50
00:02:16,660 --> 00:02:13,610
which is the largest astronomical

51
00:02:18,690 --> 00:02:16,670
of the year so we're skipping that one

52
00:02:21,520 --> 00:02:18,700
and we're doing it on the third Tuesday

53
00:02:23,320 --> 00:02:21,530
and we're this is a really cool stuff

54
00:02:25,870 --> 00:02:23,330
that actually will probably be talked

55
00:02:28,300 --> 00:02:25,880
about a lot at the AAAS meeting initial

56
00:02:30,310 --> 00:02:28,310
exoplanet discoveries with Tess Tessa's

57
00:02:33,520 --> 00:02:30,320
and knew the transiting exoplanet survey

58
00:02:35,710 --> 00:02:33,530
satellite brand new discoveries really

59
00:02:39,460 --> 00:02:35,720
cool stuff and Scott Fleming will be

60
00:02:43,810 --> 00:02:39,470
talking about them all right so if you

61
00:02:46,990 --> 00:02:43,820
want all the details website if you go

62
00:02:49,420 --> 00:02:47,000
to hubble site you'll find us on there

63
00:02:50,890 --> 00:02:49,430

you can use your web browser and search

64
00:02:53,170 --> 00:02:50,900
for Hubble public talks and you should

65
00:02:54,940 --> 00:02:53,180
find this we have links to our web

66
00:02:58,390 --> 00:02:54,950
casting we have links to our past

67
00:03:01,560 --> 00:02:58,400
lectures you can sign up for our email

68
00:03:04,390 --> 00:03:01,570
list and get all the information there

69
00:03:06,610 --> 00:03:04,400
our email are just basically two

70
00:03:08,410 --> 00:03:06,620
announcements a month if you can't sign

71
00:03:09,840 --> 00:03:08,420
up at the website you write your name on

72
00:03:12,370 --> 00:03:09,850
a piece of paper hand it to me

73
00:03:14,740 --> 00:03:12,380
I'll make sure you get on there and

74
00:03:16,180 --> 00:03:14,750
again as always if you have comments or

75
00:03:21,940 --> 00:03:16,190
questions you can send them to the email

76
00:03:23,320 --> 00:03:21,950
address public lecture at stsci edu for

77
00:03:25,930 --> 00:03:23,330
those of you who do social media we're

78
00:03:28,240 --> 00:03:25,940
on Facebook Twitter YouTube Instagram I

79
00:03:31,570 --> 00:03:28,250
myself of a lot I'm on those sometimes

80
00:03:33,850 --> 00:03:31,580
if you sort of find that this is mostly

81
00:03:36,850 --> 00:03:33,860
for the web audience and they can pause

82
00:03:39,850 --> 00:03:36,860
it and copy down these addresses all

83
00:03:42,040 --> 00:03:39,860
right the observatory is not open

84
00:03:44,080 --> 00:03:42,050
tonight because it's under repair okay

85
00:03:45,940 --> 00:03:44,090
it's actually probably it looks like it

86
00:03:47,860 --> 00:03:45,950
was a reasonable reasonable night for it

87
00:03:50,680 --> 00:03:47,870
somebody say all right now not quite all

88
00:03:53,199 --> 00:03:50,690

right so maybe it wasn't but it's not

89
00:03:55,630 --> 00:03:53,209
open anyways so you'll have to go to MD

90
00:03:58,540 --> 00:03:55,640
that space granorg check out their

91
00:04:00,070 --> 00:03:58,550
Friday night open houses while it's

92
00:04:02,080 --> 00:04:00,080
under repair I'm assuming they're not

93
00:04:04,210 --> 00:04:02,090
going to have it but if you go to that

94
00:04:06,759 --> 00:04:04,220
webpage there and check the observatory

95
00:04:08,770 --> 00:04:06,769
status you will be able to find out

96
00:04:12,220 --> 00:04:08,780
whether they are doing observing each

97
00:04:13,030 --> 00:04:12,230
and every Friday night we have a special

98
00:04:15,880 --> 00:04:13,040
announcement

99
00:04:17,170 --> 00:04:15,890
because Space Telescope and NASA are

100
00:04:20,380 --> 00:04:17,180
working with a Maryland Institute

101
00:04:22,810 --> 00:04:20,390
College of Art mica on a special

102
00:04:25,510 --> 00:04:22,820
presentation called painting the sky in

103
00:04:27,400 --> 00:04:25,520
gamma-rays celebrating 10

104
00:04:30,159 --> 00:04:27,410
years of the Fermi gamma-ray Space

105
00:04:33,010 --> 00:04:30,169
Telescope and there's one thing you can

106
00:04:35,680 --> 00:04:33,020
say about mica you may not love what

107
00:04:39,070 --> 00:04:35,690
they do but it's never boring

108
00:04:41,430 --> 00:04:39,080
okay and so mica is now taking on gamma

109
00:04:43,749 --> 00:04:41,440
rays all right when is this happening

110
00:04:46,649 --> 00:04:43,759
the bottom half of this advertisement

111
00:04:49,779 --> 00:04:46,659
tells you it's on Sunday October 14th

112
00:04:51,999 --> 00:04:49,789
the doors open at 6:30 the show is at

113
00:04:54,960 --> 00:04:52,009

7:00 all of the artwork and everything

114
00:04:57,399 --> 00:04:54,970
has been curated by both artists and

115
00:04:59,589 --> 00:04:57,409
astronomers or some and the presentation

116
00:05:01,899 --> 00:04:59,599
will be by both of them so it should be

117
00:05:03,520 --> 00:05:01,909
an interesting evening and what you see

118
00:05:06,300 --> 00:05:03,530
down here at the bottom is the Baltimore

119
00:05:10,420 --> 00:05:06,310
skyline and above it is the gamma-ray

120
00:05:13,570 --> 00:05:10,430
all-sky map from Fermi so gamma rays and

121
00:05:17,110 --> 00:05:13,580
mica all right if you want to attend

122
00:05:19,629 --> 00:05:17,120
that and now the news from the universe

123
00:05:22,330 --> 00:05:19,639
not for September of 2018 I obviously

124
00:05:28,620 --> 00:05:22,340
didn't change this slide today haha but

125
00:05:31,529 --> 00:05:28,630
for October 2018 first story tonight

126
00:05:34,899 --> 00:05:31,539
gravitational lensing and buffalo wings

127
00:05:39,430 --> 00:05:34,909
as you all know I love coming up with

128
00:05:42,640 --> 00:05:39,440
interesting titles so a few years ago I

129
00:05:45,430 --> 00:05:42,650
ran a visualization wall here in the

130
00:05:46,959 --> 00:05:45,440
building it wasn't this big but the

131
00:05:49,269 --> 00:05:46,969
point of a visualization wall is that

132
00:05:51,309 --> 00:05:49,279
you can see lots and lots and lots of

133
00:05:53,589 --> 00:05:51,319
pixels matter of fact my visualization

134
00:05:54,969 --> 00:05:53,599
wall was the only place in the building

135
00:05:57,760 --> 00:05:54,979
that you could see the brand-new

136
00:06:00,850 --> 00:05:57,770
advanced camera survey images pixel for

137
00:06:04,330 --> 00:06:00,860
pixel so I got to see a lot of the

138
00:06:06,490 --> 00:06:04,340

really fresh data straight off off the

139
00:06:09,430 --> 00:06:06,500
telescope because people would bring it

140
00:06:11,620 --> 00:06:09,440
to my office and they look at it and one

141
00:06:14,830 --> 00:06:11,630
of the most amazing images I ever got to

142
00:06:18,640 --> 00:06:14,840
see was the original image of this get

143
00:06:22,059 --> 00:06:18,650
galaxy cluster Abell 1689 this is a

144
00:06:24,820 --> 00:06:22,069
massive galaxy cluster so massive that

145
00:06:26,680 --> 00:06:24,830
the mass of the cluster distorts space

146
00:06:28,629 --> 00:06:26,690
and produces an effect called

147
00:06:30,279 --> 00:06:28,639
gravitational lensing okay

148
00:06:33,129 --> 00:06:30,289
so light that passes through that

149
00:06:36,070 --> 00:06:33,139
cluster gets stretched and warped and

150
00:06:38,829 --> 00:06:36,080
magnified and amplified in strange ways

151
00:06:39,430 --> 00:06:38,839
and you see these streaky are key things

152
00:06:42,310 --> 00:06:39,440
I mean

153
00:06:44,740 --> 00:06:42,320
in on it okay you can see all these

154
00:06:47,350 --> 00:06:44,750
strange streaks and arcs those are the

155
00:06:49,270 --> 00:06:47,360
gravitationally lensed galaxies galaxies

156
00:06:51,910 --> 00:06:49,280
behind the cluster whose light has been

157
00:06:54,520 --> 00:06:51,920
stretched out while it passes through

158
00:06:56,650 --> 00:06:54,530
the cluster and when Mark postman

159
00:06:58,240 --> 00:06:56,660
brought this into my office we looked at

160
00:07:00,700 --> 00:06:58,250
it and we were like floored because

161
00:07:03,520 --> 00:07:00,710
there was gravitational lensing across

162
00:07:05,860 --> 00:07:03,530
the entire image all the way out to the

163
00:07:08,320 --> 00:07:05,870

edges and which really meant that you

164
00:07:10,390 --> 00:07:08,330
know Hubble is capturing a lot of really

165
00:07:13,240 --> 00:07:10,400
great gravitational lensing but there's

166
00:07:15,940 --> 00:07:13,250
still more to see outside of this beyond

167
00:07:18,370 --> 00:07:15,950
Hubble's field of view and that has been

168
00:07:20,650 --> 00:07:18,380
true for a lot of the gravitationally

169
00:07:22,270 --> 00:07:20,660
lens clusters we've looked at one of the

170
00:07:25,930 --> 00:07:22,280
ones we've looked at the most often has

171
00:07:28,630 --> 00:07:25,940
been galaxy cluster Abell 370 okay and

172
00:07:32,140 --> 00:07:28,640
it's really famous because it has the

173
00:07:34,750 --> 00:07:32,150
dragon all right so this gravitationally

174
00:07:37,810 --> 00:07:34,760
lensed arc is actually like a it's three

175
00:07:40,510 --> 00:07:37,820
or five images of the same galaxy but

176
00:07:42,100 --> 00:07:40,520
all stretched out together in a form

177
00:07:43,810 --> 00:07:42,110
that somebody'd nicknamed the dragon

178
00:07:49,600 --> 00:07:43,820
okay and that's sort of what made a bell

179
00:07:51,580 --> 00:07:49,610
370 famous but just like with 1689 we

180
00:07:53,670 --> 00:07:51,590
look at it and we see the gravitational

181
00:07:56,230 --> 00:07:53,680
lensing there but we don't get to see

182
00:07:57,580 --> 00:07:56,240
what's around it although gravity all

183
00:08:01,720 --> 00:07:57,590
the full extent of the gravitational

184
00:08:04,930 --> 00:08:01,730
lensing until a brand-new project has

185
00:08:07,090 --> 00:08:04,940
has come up and it has her tortured

186
00:08:10,720 --> 00:08:07,100
record him like a lot of astronomy

187
00:08:14,620 --> 00:08:10,730
projects beyond ultra deep frontier

188
00:08:16,780 --> 00:08:14,630

fields and legacy observations yes

189
00:08:19,690 --> 00:08:16,790
they got buffalo together even to that

190
00:08:22,060 --> 00:08:19,700
as their academic so the Buffalo Survey

191
00:08:25,120 --> 00:08:22,070
which is a project to try and you know

192
00:08:26,860 --> 00:08:25,130
extend out and really get gravitational

193
00:08:29,710 --> 00:08:26,870
lensing as well as Hubble can do it

194
00:08:32,740 --> 00:08:29,720
they've looked at a Bell 370 and instead

195
00:08:35,709 --> 00:08:32,750
of this region they are taking that much

196
00:08:37,240 --> 00:08:35,719
region in okay so this is their first

197
00:08:39,159 --> 00:08:37,250
image that they've released from the

198
00:08:41,170 --> 00:08:39,169
project just say hey the project is

199
00:08:42,490 --> 00:08:41,180
going and we're getting really good data

200
00:08:45,280 --> 00:08:42,500
and we're seeing things and what we're

201
00:08:47,230 --> 00:08:45,290
able to do is look out and see not just

202
00:08:49,120 --> 00:08:47,240
the really strong lensing in the center

203
00:08:50,950 --> 00:08:49,130
but you get as you get further and

204
00:08:52,910 --> 00:08:50,960
further out if you've got strong lensing

205
00:08:55,309 --> 00:08:52,920
here and you go further out it becomes

206
00:08:57,439 --> 00:08:55,319
we cleansing right so you're going from

207
00:08:59,929 --> 00:08:57,449
a strongly means toward the we cleansing

208
00:09:02,299 --> 00:08:59,939
rosy regime and were able to get much

209
00:09:04,639 --> 00:09:02,309
better observations and understanding of

210
00:09:06,530 --> 00:09:04,649
the distribution of mass in this cluster

211
00:09:08,660 --> 00:09:06,540
which is what gravitational lensing

212
00:09:10,549 --> 00:09:08,670
really tells you about cuz you can see

213
00:09:12,979 --> 00:09:10,559

where the galaxies are but where is the

214
00:09:15,499 --> 00:09:12,989
mass and in particular the dark matter

215
00:09:17,809 --> 00:09:15,509
of the universe how is that distributed

216
00:09:19,909 --> 00:09:17,819
and so the Buffalo project will be able

217
00:09:22,549 --> 00:09:19,919
to do that on larger scales giving us

218
00:09:24,979 --> 00:09:22,559
finer details and more understanding of

219
00:09:27,489 --> 00:09:24,989
the largest collapsed structures in the

220
00:09:31,009 --> 00:09:27,499
universe these giant galaxies clusters

221
00:09:33,530 --> 00:09:31,019
so the joke is of course that by looking

222
00:09:36,499 --> 00:09:33,540
in the wings in the buffalo wings of the

223
00:09:39,619 --> 00:09:36,509
cluster we're going to get a lot of new

224
00:09:43,939 --> 00:09:39,629
information yeah I'm sorry I had had to

225
00:09:49,069 --> 00:09:43,949
do that alright our second story for you

226
00:09:51,109 --> 00:09:49,079
tonight our solar system grows again aha

227
00:09:53,989 --> 00:09:51,119
everyone thinks we know all about our

228
00:09:56,119 --> 00:09:53,999
solar system we're still discovering in

229
00:09:57,559 --> 00:09:56,129
our solar system because you know when

230
00:09:59,150 --> 00:09:57,569
people think of the solar system they

231
00:10:01,699 --> 00:09:59,160
think of the Sun and the eight planets

232
00:10:03,590 --> 00:10:01,709
okay that's the central region of our

233
00:10:05,449 --> 00:10:03,600
solar system we've got you know the four

234
00:10:07,460 --> 00:10:05,459
rocky planets in close the four giant

235
00:10:10,069 --> 00:10:07,470
planets out there and that's your basic

236
00:10:12,470 --> 00:10:10,079
picture of the solar system but if

237
00:10:14,929 --> 00:10:12,480
you've been paying attention you will

238
00:10:16,759 --> 00:10:14,939

know that in the 1990s we started

239
00:10:19,100 --> 00:10:16,769
discovering a whole new region of the

240
00:10:22,460 --> 00:10:19,110
solar system and it's called the Kuiper

241
00:10:24,259 --> 00:10:22,470
belt okay and those are the orbits of

242
00:10:27,169 --> 00:10:24,269
Jupiter Saturn Uranus and Neptune and

243
00:10:30,739 --> 00:10:27,179
all those red and white dots have been

244
00:10:33,259 --> 00:10:30,749
discovered since 1992 thousands of

245
00:10:35,119 --> 00:10:33,269
objects there's small icy earth

246
00:10:38,539 --> 00:10:35,129
elliptical orbits and tilted orbit set

247
00:10:40,999 --> 00:10:38,549
cetera and Pluto is the largest of the

248
00:10:42,559 --> 00:10:41,009
Kuiper belt objects okay sorry it's not

249
00:10:44,179 --> 00:10:42,569
a planet anymore but it's it's now the

250
00:10:46,639 --> 00:10:44,189
king of the Kuiper belt if you want to

251
00:10:48,379 --> 00:10:46,649
you know feel good about it okay and if

252
00:10:50,869 --> 00:10:48,389
you've really been paying attention you

253
00:10:53,059 --> 00:10:50,879
know that the Kuiper belt isn't it we

254
00:10:55,579 --> 00:10:53,069
also have a region of the solar system

255
00:10:57,169 --> 00:10:55,589
that we've never seen directly but we

256
00:11:00,829 --> 00:10:57,179
sort of seen indirectly it's the Oort

257
00:11:03,169 --> 00:11:00,839
cloud and this is a logarithmic plot so

258
00:11:06,140 --> 00:11:03,179
you can see the Orcas way way way out it

259
00:11:09,620 --> 00:11:06,150
goes out to like 50 thousand a

260
00:11:12,440 --> 00:11:09,630
whereas the earth is 1au and neptune is

261
00:11:15,230 --> 00:11:12,450
30 au and the Kuiper belt goes to 50 au

262
00:11:19,070 --> 00:11:15,240
this goes a thousand times farther out

263
00:11:21,380 --> 00:11:19,080

to 50,000 au okay and this is where the

264
00:11:23,960 --> 00:11:21,390
long period comets come from all right

265
00:11:26,480 --> 00:11:23,970
so there's a lot more to our solar

266
00:11:28,880 --> 00:11:26,490
system than you usually think and we

267
00:11:30,040 --> 00:11:28,890
hadn't really gone out beyond the Kuiper

268
00:11:34,220 --> 00:11:30,050
belt

269
00:11:37,400 --> 00:11:34,230
except we found this one strange object

270
00:11:40,130 --> 00:11:37,410
in the 90s it's not in the early 2000s

271
00:11:42,350 --> 00:11:40,140
it's called Sedna now up in the top

272
00:11:44,270 --> 00:11:42,360
there you see the orbits of the giant

273
00:11:45,260 --> 00:11:44,280
planets and I think that purple one is

274
00:11:47,810 --> 00:11:45,270
the orbit of Pluto

275
00:11:50,480 --> 00:11:47,820
okay so Pluto gives you the the scale of

276
00:11:54,260 --> 00:11:50,490
the Kuiper belt you can see said nações

277
00:11:57,800 --> 00:11:54,270
way way way out Sedna at its closest is

278
00:12:01,550 --> 00:11:57,810
like 75 au and it goes all the way out

279
00:12:04,190 --> 00:12:01,560
to almost a thousand au what the heck is

280
00:12:06,410 --> 00:12:04,200
it doing there okay it's sort of beyond

281
00:12:09,110 --> 00:12:06,420
the realm of the Kuiper belt but it's

282
00:12:11,660 --> 00:12:09,120
inside the realm of the Oort cloud and

283
00:12:13,420 --> 00:12:11,670
it was really hard to understand how you

284
00:12:16,370 --> 00:12:13,430
could get an object sitting there and

285
00:12:19,880 --> 00:12:16,380
then we found hey you know what

286
00:12:22,670 --> 00:12:19,890
it isn't the only one all of these

287
00:12:24,140 --> 00:12:22,680
objects are you can see Sedna's orbit

288
00:12:25,790 --> 00:12:24,150

here in the dark purple and all the

289
00:12:27,590 --> 00:12:25,800
light purple objects have been

290
00:12:29,030 --> 00:12:27,600
discovered and they have similar object

291
00:12:31,250 --> 00:12:29,040
we got half a dozen or so of these

292
00:12:33,440 --> 00:12:31,260
objects that are sitting out in sort of

293
00:12:38,360 --> 00:12:33,450
a no-man's land of the solar system and

294
00:12:41,720 --> 00:12:38,370
that is what caused Mike Brown and his

295
00:12:45,050 --> 00:12:41,730
colleagues to suppose hypothesize that

296
00:12:46,910 --> 00:12:45,060
there was this actual planet 9 after

297
00:12:49,280 --> 00:12:46,920
getting rid of Pluto is Planet 9 they

298
00:12:51,710 --> 00:12:49,290
brought it back as a hypothesis to

299
00:12:53,300 --> 00:12:51,720
explain all of these orbits that are out

300
00:12:55,700 --> 00:12:53,310
sort of in this no-man's land of the

301
00:12:58,250 --> 00:12:55,710
solar system so they have been looking

302
00:13:00,920 --> 00:12:58,260
for planet 9 for a couple years they

303
00:13:04,250 --> 00:13:00,930
proposed this in 2015 and they've got

304
00:13:07,460 --> 00:13:04,260
some searches underway and yesterday

305
00:13:10,250 --> 00:13:07,470
they announced no they didn't announce

306
00:13:16,280 --> 00:13:10,260
Planet nine but they announced a new

307
00:13:18,830 --> 00:13:16,290
object 2015 TG 387 now take a look at

308
00:13:20,740 --> 00:13:18,840
this scale you see Sedna they're going

309
00:13:24,080 --> 00:13:20,750
out to a thousand au

310
00:13:25,970 --> 00:13:24,090
EEG which is which they call short for

311
00:13:28,070 --> 00:13:25,980
the Goblin TG because it was discovered

312
00:13:33,560 --> 00:13:28,080
around Halloween three years ago goes

313
00:13:36,490 --> 00:13:33,570

out to 2300 au the solar system size of

314
00:13:40,610 --> 00:13:36,500
what we've observed has just doubled

315
00:13:42,770 --> 00:13:40,620
yeah and this what's significant about

316
00:13:44,840 --> 00:13:42,780
this is this is starting to get out to

317
00:13:45,260 --> 00:13:44,850
the area of the inner edge of the Kuiper

318
00:13:51,770 --> 00:13:45,270
belt

319
00:13:53,690 --> 00:13:51,780
okay so TG 387 is going out to where the

320
00:13:56,300 --> 00:13:53,700
sort of the inner edge but it still

321
00:13:59,360 --> 00:13:56,310
comes in and is out is sort of well

322
00:14:01,310 --> 00:13:59,370
beyond the Kuiper belt when they analyze

323
00:14:03,020 --> 00:14:01,320
this and it took them three years by the

324
00:14:04,730 --> 00:14:03,030
way to get this orbit okay they

325
00:14:06,980 --> 00:14:04,740
discovered it in 2015 it took them three

326
00:14:08,420 --> 00:14:06,990
years of follow-up observations in order

327
00:14:10,580 --> 00:14:08,430
to determine this up so there's orbit

328
00:14:14,750 --> 00:14:10,590
because it's moving so bloody slowly

329
00:14:18,020 --> 00:14:14,760
okay and when they analyzed it they

330
00:14:23,030 --> 00:14:18,030
found it was it too was consistent with

331
00:14:25,220 --> 00:14:23,040
a hypothesis of Planet 9 so they had

332
00:14:27,530 --> 00:14:25,230
doubled the size of the object of the

333
00:14:29,390 --> 00:14:27,540
the orbits of the things we've seen in

334
00:14:31,100 --> 00:14:29,400
the solar system and they found yet

335
00:14:33,470 --> 00:14:31,110
another object that seems to lend

336
00:14:35,510 --> 00:14:33,480
credence to the hypothesis that there is

337
00:14:38,960 --> 00:14:35,520
this you know several earth mass type

338
00:14:40,430 --> 00:14:38,970

planet out beyond the Kuiper belt they

339
00:14:43,820 --> 00:14:40,440
haven't discovered that yet they're

340
00:14:46,490 --> 00:14:43,830
still going to keep looking but hey our

341
00:14:49,850 --> 00:14:46,500
solar system just got a little bit

342
00:14:54,230 --> 00:14:49,860
bigger we're still discovering things in

343
00:14:56,780 --> 00:14:54,240
our own backyard and on that how big is

344
00:14:58,820 --> 00:14:56,790
the object the object is about 300

345
00:15:02,270 --> 00:14:58,830
kilometers in diameter as an estimate

346
00:15:04,070 --> 00:15:02,280
okay it's not well not well resolved so

347
00:15:04,580 --> 00:15:04,080
it's about 300 kilometers so it might be

348
00:15:07,040 --> 00:15:04,590
spherical

349
00:15:11,290 --> 00:15:07,050
so they actually in the press release

350
00:15:13,580 --> 00:15:11,300
called it an extreme dwarf planet I

351
00:15:15,910 --> 00:15:13,590
deleted that text from this diagram

352
00:15:18,710 --> 00:15:15,920
because I don't think it's justified yet

353
00:15:22,370 --> 00:15:18,720
but it could be a dwarf planet by the

354
00:15:24,380 --> 00:15:22,380
AAA use convention by being 300 it might

355
00:15:28,220 --> 00:15:24,390
be spherical but it might not be at 300

356
00:15:32,270 --> 00:15:28,230
kilometers so we're not quite sure all

357
00:15:33,700 --> 00:15:32,280
the details of it but hey there's still

358
00:15:41,430 --> 00:15:33,710
something new Under the Sun

359
00:15:46,420 --> 00:15:44,590
okay so the question is do they have a

360
00:15:48,550 --> 00:15:46,430
guess about what the composition of

361
00:15:50,170 --> 00:15:48,560
Planet 9 would be it would have to be

362
00:15:51,790 --> 00:15:50,180
several earth masses from what I

363
00:15:54,310 --> 00:15:51,800

understand it's been a while since I've

364
00:15:55,750 --> 00:15:54,320
looked at this in detail but they're

365
00:15:58,830 --> 00:15:55,760
looking at several earth masses which

366
00:16:04,480 --> 00:15:58,840
would be a rocky type planet like Earth

367
00:16:06,040 --> 00:16:04,490
okay one more question up there do I

368
00:16:09,370 --> 00:16:06,050
have any idea what the periastron Oh

369
00:16:13,390 --> 00:16:09,380
Planet nine would be no it's not my

370
00:16:15,490 --> 00:16:13,400
field I'm more cosmology not so says the

371
00:16:17,980 --> 00:16:15,500
so I have to bone up when I do these

372
00:16:20,080 --> 00:16:17,990
presentations but I'm sure you're sure

373
00:16:22,420 --> 00:16:20,090
I'm sure if you look up Planet nine and

374
00:16:25,000 --> 00:16:22,430
such there are several papers available

375
00:16:26,230 --> 00:16:25,010
on it that might be able to show you the

376
00:16:28,870 --> 00:16:26,240
parameter space that they're looking to

377
00:16:33,640 --> 00:16:28,880
try and find this hypothesized object

378
00:16:36,640 --> 00:16:33,650
okay all right and so now we go over to

379
00:16:40,330 --> 00:16:36,650
our featured speaker and our featured

380
00:16:42,460 --> 00:16:40,340
speaker tonight is Gotham Narayan he

381
00:16:45,070 --> 00:16:42,470
came to us for you started out you did

382
00:16:49,060 --> 00:16:45,080
your graduate work at Harvard and then

383
00:16:51,970 --> 00:16:49,070
went to NOAA Oh as a postdoc and then

384
00:16:54,370 --> 00:16:51,980
came here as a Barry Lasker fellow and

385
00:16:56,950 --> 00:16:54,380
is now working in this science mission

386
00:16:59,770 --> 00:16:56,960
office here at the Space Telescope

387
00:17:01,060 --> 00:16:59,780
Science Institute and I'm really looking

388
00:17:01,660 --> 00:17:01,070

forward to this talk so let's give him a

389
00:17:03,030 --> 00:17:01,670
warm hand

390
00:17:10,080 --> 00:17:03,040
Gotha narayan

391
00:17:26,500 --> 00:17:12,390
can you all hear me okay

392
00:17:29,170 --> 00:17:26,510
okay so let's wake this thing up alright

393
00:17:32,170 --> 00:17:29,180
so the title of this talk is chasing

394
00:17:33,790 --> 00:17:32,180
supernovae with Kepler but I learnt very

395
00:17:35,560 --> 00:17:33,800
long ago from Stanley Kubrick that I

396
00:17:38,020 --> 00:17:35,570
should always name things after what

397
00:17:39,580 --> 00:17:38,030
they actually are about so this isn't

398
00:17:42,280 --> 00:17:39,590
really about chasing supernovae with

399
00:17:43,810 --> 00:17:42,290
Kepler it's it's about how we commandeer

400
00:17:46,110 --> 00:17:43,820
the next apparent telescope to go study

401
00:17:48,810 --> 00:17:46,120
stars that will go boom

402
00:17:52,360 --> 00:17:48,820
and that's a much more fun title I think

403
00:17:53,800 --> 00:17:52,370
this isn't a project that I am doing by

404
00:17:56,670 --> 00:17:53,810
myself there's plenty of people working

405
00:17:58,810 --> 00:17:56,680
on it these are a list of the kegerators

406
00:18:01,830 --> 00:17:58,820
collaborators on this experiment called

407
00:18:04,690 --> 00:18:01,840
kegs the Kepler extra galactic Survey

408
00:18:06,130 --> 00:18:04,700
the PI of the project is arm and rest

409
00:18:08,170 --> 00:18:06,140
whoo so the scientist here at Space

410
00:18:11,650 --> 00:18:08,180
Telescope and my mentor and so I'm

411
00:18:13,210 --> 00:18:11,660
talking about all of our work really on

412
00:18:16,080 --> 00:18:13,220
this project it's not it's a team effort

413
00:18:18,160 --> 00:18:16,090

it's a great little project that we have

414
00:18:19,810 --> 00:18:18,170
so to begin with

415
00:18:22,810 --> 00:18:19,820
how many of you have heard of Johannes

416
00:18:25,810 --> 00:18:22,820
Kepler show of hands all right a few of

417
00:18:27,130 --> 00:18:25,820
you okay so let me talk a little bit

418
00:18:29,410 --> 00:18:27,140
about the astronomer of the mission to

419
00:18:34,030 --> 00:18:29,420
solve with Yanis Kepler was the Imperial

420
00:18:35,680 --> 00:18:34,040
mathematician in Graz and he was an

421
00:18:37,260 --> 00:18:35,690
assistant to another famous astronomer

422
00:18:41,350 --> 00:18:37,270
Tycho Brahe he's a contemporary of

423
00:18:43,660 --> 00:18:41,360
Galileo Galilei but he was a smart man

424
00:18:45,970 --> 00:18:43,670
and Galileo for a couple of reasons the

425
00:18:47,530 --> 00:18:45,980
first reason was that Kepler was a very

426
00:18:49,180 --> 00:18:47,540
good optical scientist and learned how

427
00:18:51,340 --> 00:18:49,190
to make really good telescopes in fact

428
00:18:54,430 --> 00:18:51,350
we call most astronomical telescopes

429
00:18:56,110 --> 00:18:54,440
today Keplerian telescopes they have two

430
00:18:58,270 --> 00:18:56,120
convex lenses and this was much better

431
00:19:01,000 --> 00:18:58,280
than Galileo's design of a convex and a

432
00:19:03,940 --> 00:19:01,010
concave lens because it allowed him to

433
00:19:06,580 --> 00:19:03,950
measure distances in angular distances

434
00:19:08,890 --> 00:19:06,590
very precisely he could find the

435
00:19:10,870 --> 00:19:08,900
separation between two stars on the sky

436
00:19:13,440 --> 00:19:10,880
through his telescope much more

437
00:19:15,910 --> 00:19:13,450
precisely than anybody else in his day

438
00:19:18,850 --> 00:19:15,920

that led him to be able to make very

439
00:19:19,510 --> 00:19:18,860
very precise measurements of the motion

440
00:19:21,550 --> 00:19:19,520
of

441
00:19:24,070 --> 00:19:21,560
and planets in the sky he could study

442
00:19:25,750 --> 00:19:24,080
these things very very accurately and he

443
00:19:28,030 --> 00:19:25,760
took very beautiful detailed

444
00:19:30,970 --> 00:19:28,040
measurements off these things recording

445
00:19:33,130 --> 00:19:30,980
them in notebooks so his observations of

446
00:19:35,320 --> 00:19:33,140
the planets in Mars in particular

447
00:19:37,780 --> 00:19:35,330
allowed him to determine something very

448
00:19:41,050 --> 00:19:37,790
important their orbits like you saw for

449
00:19:43,270 --> 00:19:41,060
Sedna and the Goblin in that wonderful

450
00:19:45,640 --> 00:19:43,280
little talk by Frank their orbits

451
00:19:47,860 --> 00:19:45,650
weren't circles right they were

452
00:19:50,200 --> 00:19:47,870
elliptical they were sort of circle

453
00:19:52,870 --> 00:19:50,210
except you take additional direction and

454
00:19:54,720 --> 00:19:52,880
so in his notebook Kepler was the first

455
00:19:58,150 --> 00:19:54,730
person to actually describe this

456
00:20:01,510 --> 00:19:58,160
circular motion this elliptical motion

457
00:20:03,520 --> 00:20:01,520
rather showing you here how a circle

458
00:20:05,560 --> 00:20:03,530
looks versus the geometry of an ellipse

459
00:20:08,020 --> 00:20:05,570
around it this is the second reason that

460
00:20:10,450 --> 00:20:08,030
Kepler is smarter man than Galileo while

461
00:20:11,790 --> 00:20:10,460
Galileo was getting in trouble with the

462
00:20:14,110 --> 00:20:11,800
church for his heretical teachings

463
00:20:16,480 --> 00:20:14,120

Kepler sensibly added angels to his

464
00:20:26,590 --> 00:20:16,490
plots so that kept him on the good side

465
00:20:29,590 --> 00:20:26,600
of things so in honor of Kepler's

466
00:20:32,560 --> 00:20:29,600
pioneering work NASA named it's big

467
00:20:34,480 --> 00:20:32,570
exoplanet flagship mission after him the

468
00:20:36,340 --> 00:20:34,490
Kepler mission this is the Kepler

469
00:20:37,960 --> 00:20:36,350
satellite you actually walked by a model

470
00:20:39,880 --> 00:20:37,970
of this thing as you entered Space

471
00:20:42,040 --> 00:20:39,890
Telescope and as you heading out take a

472
00:20:43,360 --> 00:20:42,050
look and take a look on your left as

473
00:20:45,700 --> 00:20:43,370
you're walking out the glass doors and

474
00:20:49,000 --> 00:20:45,710
you'll see a see there it's a beautiful

475
00:20:51,520 --> 00:20:49,010
thing and this entire mission has been

476
00:20:53,050 --> 00:20:51,530
incredibly successful this isn't of

477
00:20:55,600 --> 00:20:53,060
course the only way we honor Kepler I

478
00:21:00,880 --> 00:20:55,610
named my dog after him as well this is

479
00:21:02,880 --> 00:21:00,890
kept up a dog so let me tell you a

480
00:21:05,050 --> 00:21:02,890
little bit about how Kepler works

481
00:21:06,880 --> 00:21:05,060
that's the satellite over there going

482
00:21:08,350 --> 00:21:06,890
around the Sun and you can see it's

483
00:21:10,360 --> 00:21:08,360
oriented in roughly the same direction

484
00:21:12,220 --> 00:21:10,370
it's pointing at solar cell panels at

485
00:21:13,600 --> 00:21:12,230
towards the Sun at all times and it's

486
00:21:17,500 --> 00:21:13,610
staring in roughly the same direction in

487
00:21:19,600 --> 00:21:17,510
space and it's staring at stars and it's

488
00:21:22,930 --> 00:21:19,610

looking for planets that go around stars

489
00:21:25,690 --> 00:21:22,940
and when a planet does pass in front of

490
00:21:27,600 --> 00:21:25,700
a star what you can see down here is

491
00:21:30,670 --> 00:21:27,610
that the brightness of the star drops

492
00:21:32,500 --> 00:21:30,680
right so this is a how bright the star

493
00:21:33,289 --> 00:21:32,510
is is a function of time so time is

494
00:21:37,450 --> 00:21:33,299
marching this

495
00:21:40,909 --> 00:21:37,460
Way and star goes a front drop come back

496
00:21:43,310 --> 00:21:40,919
and Kepler is seeing hundreds and

497
00:21:45,619 --> 00:21:43,320
thousands of these all the time these

498
00:21:49,580 --> 00:21:45,629
things are called transits and this

499
00:21:52,100 --> 00:21:49,590
particular form of of a plot is of

500
00:21:54,049 --> 00:21:52,110
brightness versus time is something

501
00:21:56,090 --> 00:21:54,059
we'll call a light curves and I'll come

502
00:22:00,710 --> 00:21:56,100
back to why that's important for most of

503
00:22:04,159 --> 00:22:00,720
the stock so this is the capital field

504
00:22:07,190 --> 00:22:04,169
of view and it's found in the course of

505
00:22:10,070 --> 00:22:07,200
its primary mission several thousands of

506
00:22:12,019 --> 00:22:10,080
planets this is our solar system for

507
00:22:13,999 --> 00:22:12,029
scale and as you can see most of the

508
00:22:15,739 --> 00:22:14,009
systems it's finding look nothing like

509
00:22:17,960 --> 00:22:15,749
our solar system our solar systems kind

510
00:22:20,389 --> 00:22:17,970
of odd this might be because the Kepler

511
00:22:22,849 --> 00:22:20,399
is sort of finding planets that are

512
00:22:25,099 --> 00:22:22,859
around hotter stars they're brighter and

513
00:22:27,229 --> 00:22:25,109

also finding bigger planets but it is

514
00:22:29,930 --> 00:22:27,239
still a tremendously successful mission

515
00:22:32,029 --> 00:22:29,940
and it is has been really just an

516
00:22:35,989 --> 00:22:32,039
incredible incredibly revolutionary tool

517
00:22:42,349 --> 00:22:35,999
for our field but I'm not interested in

518
00:22:44,930 --> 00:22:42,359
planets like most kids growing up I was

519
00:22:47,450 --> 00:22:44,940
interested in sci-fi I was interested in

520
00:22:51,739 --> 00:22:47,460
Star Wars I was interested in Star Trek

521
00:22:53,659 --> 00:22:51,749
I loved Superman and so I was left with

522
00:22:55,820 --> 00:22:53,669
this image of what I actually wanted to

523
00:22:56,930 --> 00:22:55,830
happen to planets around stars from

524
00:22:59,629 --> 00:22:56,940
Superman does everybody remember

525
00:23:04,460 --> 00:22:59,639
Superman what planet the super might

526
00:23:07,489 --> 00:23:04,470
come from Krypton so ed shia who is an

527
00:23:10,009 --> 00:23:07,499
astronomer at UMD i was looking as a

528
00:23:11,960 --> 00:23:10,019
some planetary system or what he thought

529
00:23:14,539 --> 00:23:11,970
was battery system and something very

530
00:23:18,139 --> 00:23:14,549
odd happened instead of getting fainter

531
00:23:19,970 --> 00:23:18,149
with the planet going getting you know

532
00:23:21,830 --> 00:23:19,980
causing the light of the star to reduce

533
00:23:24,320 --> 00:23:21,840
when it goes to the front of it this

534
00:23:25,549 --> 00:23:24,330
thing of brighter and he remembered he

535
00:23:27,769 --> 00:23:25,559
said on the state this beautiful quote

536
00:23:28,999 --> 00:23:27,779
and how science works he remembers not

537
00:23:31,279 --> 00:23:29,009
knowing whether he should believe it or

538
00:23:32,810 --> 00:23:31,289

not did I make a mistake am i doing this

539
00:23:34,729 --> 00:23:32,820
all wrong this is hardly what you Rekha

540
00:23:36,320 --> 00:23:34,739
and Archimedes is like but this is

541
00:23:39,349 --> 00:23:36,330
actually how we do science for you we

542
00:23:41,450 --> 00:23:39,359
doubt ourselves all the time but it was

543
00:23:43,430 --> 00:23:41,460
right what he'd found was something that

544
00:23:45,379 --> 00:23:43,440
we had known about for a while

545
00:23:46,499 --> 00:23:45,389
it's a supernova and if you have seen

546
00:23:49,139 --> 00:23:46,509
Superman

547
00:23:53,549 --> 00:23:49,149
recognize this kind of thing so this is

548
00:23:55,079 --> 00:23:53,559
the planet Krypton and in just a second

549
00:23:58,019 --> 00:23:55,089
you should hear Marlon Brando's soothing

550
00:23:59,759 --> 00:23:58,029
voice come over the loudspeakers telling

551
00:24:03,359 --> 00:23:59,769
me telling you that telling his son

552
00:24:05,099 --> 00:24:03,369
kal-el that he will always be around

553
00:24:07,499 --> 00:24:05,109
that's that subin's little cradle

554
00:24:09,989 --> 00:24:07,509
shooting off the world and we're zooming

555
00:24:11,759 --> 00:24:09,999
out here from the planet Krypton in your

556
00:24:13,469 --> 00:24:11,769
life and we're seeing why Krypton is

557
00:24:16,049 --> 00:24:13,479
doomed and why Superman actually happens

558
00:24:18,899 --> 00:24:16,059
listen Superman is happening because the

559
00:24:22,019 --> 00:24:18,909
current Krypton is around a giant red

560
00:24:26,479 --> 00:24:22,029
star that is going to have something

561
00:24:26,489 --> 00:24:35,539
bounced

562
00:24:40,769 --> 00:24:39,269
that's a supernova that's one things and

563
00:24:43,399 --> 00:24:40,779

as you can see the planet Krypton is not

564
00:24:51,869 --> 00:24:49,099
at least and actually pretty accurate

565
00:24:55,079 --> 00:24:51,879
that is actually how quickly a star will

566
00:24:55,559 --> 00:24:55,089
collapse now we've known about supernova

567
00:24:57,180 --> 00:24:55,569
for a while

568
00:25:00,359 --> 00:24:57,190
Kepler himself found this this is the

569
00:25:02,879 --> 00:25:00,369
intro slide again of the talk and this

570
00:25:04,799 --> 00:25:02,889
is from Kepler's own book this is from

571
00:25:08,039 --> 00:25:04,809
his book called a stellar Nova in Paris

572
00:25:12,569 --> 00:25:08,049
serpent ari the new star in the foot of

573
00:25:14,009 --> 00:25:12,579
the serpent over here with an N so back

574
00:25:17,339 --> 00:25:14,019
in a on October 9th

575
00:25:18,959 --> 00:25:17,349
in 1684 a bunch of Italian astronomers

576
00:25:20,729 --> 00:25:18,969
looked up and saw something that they

577
00:25:22,439 --> 00:25:20,739
have never seen before the heavens

578
00:25:26,039 --> 00:25:22,449
changed literally this thing that they

579
00:25:28,949 --> 00:25:26,049
thought was static and uncapable of ever

580
00:25:31,469 --> 00:25:28,959
changing and was perfect suddenly had an

581
00:25:35,879 --> 00:25:31,479
F star in it that they could see with

582
00:25:37,919 --> 00:25:35,889
their eyes in day for three weeks they

583
00:25:39,749 --> 00:25:37,929
had no idea what this was well this is a

584
00:25:41,219 --> 00:25:39,759
portent could this mean something

585
00:25:43,379 --> 00:25:41,229
tremendous is going to happen

586
00:25:46,289 --> 00:25:43,389
Kepler with his telescope could study

587
00:25:48,239 --> 00:25:46,299
this for a year he collected not just

588
00:25:50,430 --> 00:25:48,249

observations on it from himself but also

589
00:25:52,199 --> 00:25:50,440
observations from all of the other

590
00:25:54,779 --> 00:25:52,209
astronomers of that time it's one of our

591
00:25:58,019 --> 00:25:54,789
best records of how astronomy was done

592
00:25:59,849 --> 00:25:58,029
in the 17th century and so we know a lot

593
00:26:00,430 --> 00:25:59,859
about this star we know exactly where it

594
00:26:01,930 --> 00:26:00,440
is in sky

595
00:26:04,150 --> 00:26:01,940
we know how bright it was at the time

596
00:26:07,600 --> 00:26:04,160
and how it brightness change dysfunction

597
00:26:09,580 --> 00:26:07,610
of time we know it's light curve and we

598
00:26:11,680 --> 00:26:09,590
can look at it today and this is what is

599
00:26:15,040 --> 00:26:11,690
left of the star that blew up that

600
00:26:17,050 --> 00:26:15,050
Kepler so among others this is a

601
00:26:22,450 --> 00:26:17,060
composite image and I'm going to do the

602
00:26:25,980 --> 00:26:22,460
CSI thing and hit enhance which well

603
00:26:29,950 --> 00:26:25,990
maybe happen if my computer wakes up

604
00:26:32,980 --> 00:26:29,960
there yeah so this is an enhanced view

605
00:26:34,450 --> 00:26:32,990
of the same image and it has four colors

606
00:26:38,110 --> 00:26:34,460
telling you different bits of

607
00:26:40,300 --> 00:26:38,120
information the the blue and the sort of

608
00:26:43,060 --> 00:26:40,310
greenish light are x-ray information

609
00:26:46,080 --> 00:26:43,070
from the Chandra Space Telescope these

610
00:26:49,060 --> 00:26:46,090
are hot highly energetic particles

611
00:26:51,490 --> 00:26:49,070
x-rays shooting out at us the Green is

612
00:26:53,800 --> 00:26:51,500
slightly lower energy the yellow areas

613
00:26:55,390 --> 00:26:53,810

are what we see in the visible this is

614
00:26:57,550 --> 00:26:55,400
with the Hubble Space Telescope where we

615
00:27:00,340 --> 00:26:57,560
see gas and dust left over from the

616
00:27:02,080 --> 00:27:00,350
explosion lit up by a shockwave that

617
00:27:04,240 --> 00:27:02,090
ripped through this entire star and

618
00:27:07,420 --> 00:27:04,250
finally the red is where the shockwave

619
00:27:10,870 --> 00:27:07,430
is today this is where the dust is in my

620
00:27:12,670 --> 00:27:10,880
image by the Spitzer Space Telescope so

621
00:27:15,760 --> 00:27:12,680
this is a really amazing picture you

622
00:27:16,900 --> 00:27:15,770
could see this image of a star that blew

623
00:27:19,060 --> 00:27:16,910
up in Hollywood

624
00:27:20,680 --> 00:27:19,070
and we can actually look at these things

625
00:27:23,020 --> 00:27:20,690
today and find them in the sky and

626
00:27:24,400 --> 00:27:23,030
they're really important because if

627
00:27:26,950 --> 00:27:24,410
you've ever looked at the periodic table

628
00:27:29,200 --> 00:27:26,960
of elements outside of hydrogen and

629
00:27:31,540 --> 00:27:29,210
helium which are produced in the Big

630
00:27:34,960 --> 00:27:31,550
Bang pretty much everything else down

631
00:27:36,700 --> 00:27:34,970
here is from a star so when you hear

632
00:27:41,040 --> 00:27:36,710
somebody like Carl Sagan say you are

633
00:27:45,460 --> 00:27:41,050
made of star stuff this is what he means

634
00:27:46,540 --> 00:27:45,470
every calcium atom in your teeth is from

635
00:27:49,770 --> 00:27:46,550
an exploding star

636
00:27:52,240 --> 00:27:49,780
that's something cool that you should

637
00:27:54,880 --> 00:27:52,250
now supernovae are amazingly bright

638
00:27:57,010 --> 00:27:54,890

things this is a galaxy and if you look

639
00:27:59,140 --> 00:27:57,020
at look down here you'll see a supernova

640
00:28:01,390 --> 00:27:59,150
get brighter over time and fade away

641
00:28:02,770 --> 00:28:01,400
this is its light curve again and you

642
00:28:08,950 --> 00:28:02,780
could sort of see they last for around

643
00:28:10,810 --> 00:28:08,960
30 days you can see them sort of easily

644
00:28:12,280 --> 00:28:10,820
with the telescope like Hubble but I

645
00:28:13,750 --> 00:28:12,290
want you to you know take a step back

646
00:28:16,660 --> 00:28:13,760
and get the big picture here

647
00:28:19,720 --> 00:28:16,670
this is a galaxy with something like 10

648
00:28:23,470 --> 00:28:19,730
to 100 billion stars and this one

649
00:28:25,510 --> 00:28:23,480
supernova was still so bright and so

650
00:28:28,090 --> 00:28:25,520
bright that you could see it against all

651
00:28:30,160 --> 00:28:28,100
of that that's pretty cool

652
00:28:33,250 --> 00:28:30,170
the problem of course is that they are

653
00:28:35,470 --> 00:28:33,260
kind of rare so in a galaxy with a

654
00:28:38,710 --> 00:28:35,480
hundred with ten 200 billion stars you

655
00:28:41,520 --> 00:28:38,720
can still only expect a supernova one or

656
00:28:44,890 --> 00:28:41,530
two supernovae every hundred years or so

657
00:28:47,680 --> 00:28:44,900
so to find these things you've got to

658
00:28:49,810 --> 00:28:47,690
look at lots and lots of galaxies now

659
00:28:51,610 --> 00:28:49,820
the Kepler mission was of course looking

660
00:28:53,890 --> 00:28:51,620
for exoplanets it was staring at one

661
00:28:57,160 --> 00:28:53,900
little patch of sky a little larger than

662
00:28:59,080 --> 00:28:57,170
the full moon and it was continuously

663
00:29:01,600 --> 00:28:59,090

looking at that region of sky for

664
00:29:03,280 --> 00:29:01,610
several years but because it's a small

665
00:29:05,380 --> 00:29:03,290
region of sky because there are

666
00:29:07,270 --> 00:29:05,390
relatively few galaxies in there you are

667
00:29:12,400 --> 00:29:07,280
not going to find a whole lot of

668
00:29:13,810 --> 00:29:12,410
supernovae right that makes sense but we

669
00:29:17,110 --> 00:29:13,820
are gonna get lucky every now and then

670
00:29:19,300 --> 00:29:17,120
so we did find some so these there were

671
00:29:21,670 --> 00:29:19,310
about six supernovae that we found from

672
00:29:24,310 --> 00:29:21,680
2010 to 2012 with Kepler just

673
00:29:26,800 --> 00:29:24,320
fortuitously the kind of supernovae is

674
00:29:28,300 --> 00:29:26,810
that I care about our type 1a supernovas

675
00:29:31,050 --> 00:29:28,310
and this is one of the examples of what

676
00:29:32,890 --> 00:29:31,060
you're seeing here oops

677
00:29:35,770 --> 00:29:32,900
so you see nothing nothing nothing

678
00:29:37,300 --> 00:29:35,780
explosion happens and suddenly there's a

679
00:29:44,050 --> 00:29:37,310
bright increase in the amount of light

680
00:29:46,840 --> 00:29:44,060
from this the Kepler data is spectacular

681
00:29:48,970 --> 00:29:46,850
in many ways from the ground we can

682
00:29:52,990 --> 00:29:48,980
expect typically about 40 observations

683
00:29:56,770 --> 00:29:53,000
of a supernova over its entire 30-days

684
00:30:00,010 --> 00:29:56,780
lifetime what we get with Kepler is

685
00:30:02,890 --> 00:30:00,020
something like 4,000 observations over

686
00:30:05,050 --> 00:30:02,900
its entire lifetime that's just way more

687
00:30:07,300 --> 00:30:05,060
data and in particular that's really

688
00:30:11,170 --> 00:30:07,310

useful because it lets you study just

689
00:30:12,880 --> 00:30:11,180
these sort of areas right before when

690
00:30:15,190 --> 00:30:12,890
the explosion happens and ask the

691
00:30:16,930 --> 00:30:15,200
explosions happening that's an area we

692
00:30:19,210 --> 00:30:16,940
almost can never study from the ground

693
00:30:20,650 --> 00:30:19,220
because we can simply never take enough

694
00:30:23,170 --> 00:30:20,660
images of it from ground-based

695
00:30:24,670 --> 00:30:23,180
telescopes so we found several different

696
00:30:26,950 --> 00:30:24,680
kinds of the supernovae and we've seen

697
00:30:28,150 --> 00:30:26,960
interesting physics from them we've seen

698
00:30:30,640 --> 00:30:28,160
for example

699
00:30:33,970 --> 00:30:30,650
a shock breakout of the star like you

700
00:30:35,650 --> 00:30:33,980
saw in a Hollywood movie and rip apart

701
00:30:37,150 --> 00:30:35,660
this thing and this is something we've

702
00:30:39,430 --> 00:30:37,160
just never been able to do until kept

703
00:30:40,810 --> 00:30:39,440
low but of course the challenge is still

704
00:30:44,350 --> 00:30:40,820
there we're only gonna find a few of

705
00:30:45,760 --> 00:30:44,360
these things so here's a couple of

706
00:30:47,290 --> 00:30:45,770
interesting light curves that we've seen

707
00:30:49,060 --> 00:30:47,300
from Kepler here it's this little bump

708
00:30:50,890 --> 00:30:49,070
that I talked about that's the shark

709
00:30:53,440 --> 00:30:50,900
breaker this is a start exploding

710
00:30:55,120 --> 00:30:53,450
nothing nothing nothing Boop explosion

711
00:30:57,520 --> 00:30:55,130
finally breaking out of the lair of the

712
00:31:00,190 --> 00:30:57,530
star and we just can't do this from the

713
00:31:02,080 --> 00:31:00,200

ground so we really want some way of

714
00:31:04,090 --> 00:31:02,090
hijacking Kepler commandeering Kepler

715
00:31:06,820 --> 00:31:04,100
stopping it from doing so planet science

716
00:31:08,950 --> 00:31:06,830
and doing all supernova science because

717
00:31:11,500 --> 00:31:08,960
this is just tremendous this data is

718
00:31:14,049 --> 00:31:11,510
invaluable for us but unfortunately the

719
00:31:17,520 --> 00:31:14,059
exoplanet people want this thing and

720
00:31:19,870 --> 00:31:17,530
then something horrible happened

721
00:31:22,210 --> 00:31:19,880
just as things were getting interesting

722
00:31:24,460 --> 00:31:22,220
the wheels came off Kepler this was the

723
00:31:25,960 --> 00:31:24,470
headline one of the reaction wheels they

724
00:31:26,799 --> 00:31:25,970
kept the spacecraft pointing in the

725
00:31:29,740 --> 00:31:26,809
right direction

726
00:31:31,990 --> 00:31:29,750
failed suddenly it means three of these

727
00:31:33,400 --> 00:31:32,000
things for your pitch and roll suddenly

728
00:31:36,310 --> 00:31:33,410
it had to keep spinning in one direction

729
00:31:38,410 --> 00:31:36,320
that's a problem that means it no longer

730
00:31:41,200 --> 00:31:38,420
can stay pointed to look for X planets

731
00:31:43,990 --> 00:31:41,210
all the time but that's also not really

732
00:31:48,580 --> 00:31:44,000
finding supernovae of course so we were

733
00:31:49,750 --> 00:31:48,590
you know kind of like that so and this

734
00:31:52,210 --> 00:31:49,760
kind of answers the question Murphy's

735
00:31:54,040 --> 00:31:52,220
Law is greater than Kepler's alright but

736
00:31:55,990 --> 00:31:54,050
this is NASA we're talking about this is

737
00:31:57,310 --> 00:31:56,000
the agency that you know goes where

738
00:31:59,710 --> 00:31:57,320

failure is not an option

739
00:32:02,260 --> 00:31:59,720
and so we have the best boffins there

740
00:32:04,150 --> 00:32:02,270
are and because we have the best puffins

741
00:32:07,110 --> 00:32:04,160
that are we came up with a cool solution

742
00:32:11,250 --> 00:32:07,120
for this this is just the coolest thing

743
00:32:14,710 --> 00:32:11,260
in place of a failed reaction wheel

744
00:32:18,030 --> 00:32:14,720
we're using sunlight to balance the

745
00:32:20,530 --> 00:32:18,040
spacecraft's rotation so the sunlight

746
00:32:23,049 --> 00:32:20,540
exerts a small amount of pleasure if

747
00:32:25,750 --> 00:32:23,059
it's unbalanced it can spin that

748
00:32:29,620 --> 00:32:25,760
spacecraft but if it's perfectly

749
00:32:34,150 --> 00:32:29,630
balanced the spacecraft will stay in the

750
00:32:36,880 --> 00:32:34,160
same location despite its lack of react

751
00:32:40,030 --> 00:32:36,890
of that the reaction will so if you

752
00:32:41,140 --> 00:32:40,040
point Kepler just right you can still do

753
00:32:43,120 --> 00:32:41,150
observations with it

754
00:32:46,480 --> 00:32:43,130
with only two reaction wheels with only

755
00:32:49,510 --> 00:32:46,490
this to guide or mode and this is not

756
00:32:51,610 --> 00:32:49,520
ideal if you're looking for exoplanets

757
00:32:53,410 --> 00:32:51,620
you're losing so much position and the

758
00:32:55,510 --> 00:32:53,420
ability to stay pointed exactly on stars

759
00:32:56,200 --> 00:32:55,520
but it's great if you want to find

760
00:32:57,790 --> 00:32:56,210
supernovae

761
00:32:59,320 --> 00:32:57,800
so we finally got rid of the sex of

762
00:33:00,820 --> 00:32:59,330
other people and was like yes we can

763
00:33:03,910 --> 00:33:00,830

totally do this and so we call this new

764
00:33:05,950 --> 00:33:03,920
mission k2 the second light effectively

765
00:33:07,840 --> 00:33:05,960
for k2 and now we can get these

766
00:33:11,260 --> 00:33:07,850
exquisite 30-minute cadence likers

767
00:33:13,390 --> 00:33:11,270
observations every 30 minutes over 100

768
00:33:15,070 --> 00:33:13,400
square degree field of view and we're no

769
00:33:17,830 --> 00:33:15,080
longer looking at just one patch of sky

770
00:33:20,830 --> 00:33:17,840
or we can look at something like 2,000

771
00:33:23,890 --> 00:33:20,840
to 14,000 galaxies every eighty day

772
00:33:26,080 --> 00:33:23,900
campaign with Kepler's k2 mission so

773
00:33:28,210 --> 00:33:26,090
suddenly we go from having a small

774
00:33:30,010 --> 00:33:28,220
number of supernovae to be able able to

775
00:33:31,600 --> 00:33:30,020
finding a lot more supernovae this is

776
00:33:33,580 --> 00:33:31,610
what really happened right this is the

777
00:33:34,690 --> 00:33:33,590
one part of Chi sky Kepler was looking

778
00:33:36,730 --> 00:33:34,700
at where we couldn't find a whole bunch

779
00:33:39,730 --> 00:33:36,740
of supernovae and suddenly now I'd love

780
00:33:45,640 --> 00:33:39,740
to look at a whole range of sky that's

781
00:33:47,410 --> 00:33:45,650
much way better for us and this is great

782
00:33:49,480 --> 00:33:47,420
because on the same sort of you know

783
00:33:51,580 --> 00:33:49,490
scale here's the kind of number of

784
00:33:52,660 --> 00:33:51,590
supernovae we expect to see because

785
00:33:55,030 --> 00:33:52,670
we've been following these with other

786
00:33:58,540 --> 00:33:55,040
telescopes this is every supernova

787
00:34:03,540 --> 00:33:58,550
that's happened in about the last 400

788
00:34:05,830 --> 00:34:03,550

years in 1691 in about 15 seconds

789
00:34:07,260 --> 00:34:05,840
there's a lot of these things if you

790
00:34:10,899 --> 00:34:07,270
look at large enough parts of the sky

791
00:34:12,820 --> 00:34:10,909
that's cool and so we can find a whole

792
00:34:14,379 --> 00:34:12,830
bunch of the supernovae simply because

793
00:34:16,960 --> 00:34:14,389
we're now looking over larger search

794
00:34:19,210 --> 00:34:16,970
area that's this is really tremendously

795
00:34:20,770 --> 00:34:19,220
useful for us and so we can start to do

796
00:34:23,139 --> 00:34:20,780
supernovae science with capital now the

797
00:34:24,909 --> 00:34:23,149
kinds of supernovae I care about aren't

798
00:34:27,250 --> 00:34:24,919
like that collapsing giant star that I

799
00:34:30,129 --> 00:34:27,260
showed you but are rather what happens

800
00:34:33,159 --> 00:34:30,139
when a small remnant a burnt-out remnant

801
00:34:35,200 --> 00:34:33,169
of star called a white dwarf explodes

802
00:34:37,570 --> 00:34:35,210
and it does that in two different ways

803
00:34:40,540 --> 00:34:37,580
it can either steal matter from another

804
00:34:42,369 --> 00:34:40,550
companion star over here or two of these

805
00:34:45,700 --> 00:34:42,379
white dwarfs can get ever closer to each

806
00:34:48,190 --> 00:34:45,710
other spin and then merge and then they

807
00:34:50,889 --> 00:34:48,200
explode once they hit a certain amount

808
00:34:54,290 --> 00:34:50,899
of mass gravity can no longer balanced

809
00:34:56,300 --> 00:34:54,300
sort of internal forces it has

810
00:34:57,980 --> 00:34:56,310
and that are different so these are the

811
00:35:00,320 --> 00:34:57,990
two sort of progenitor channels of

812
00:35:02,750 --> 00:35:00,330
making a type 1a supernova the kind of

813
00:35:03,980 --> 00:35:02,760

thing that I care about and there's also

814
00:35:06,560 --> 00:35:03,990
different kinds of physics that you

815
00:35:09,080 --> 00:35:06,570
might expect so you start off with a

816
00:35:10,880 --> 00:35:09,090
white dwarf and something else and then

817
00:35:12,830 --> 00:35:10,890
somehow or the other you put in some

818
00:35:14,450 --> 00:35:12,840
explosion physics over here and then you

819
00:35:16,190 --> 00:35:14,460
get this thing that blows up called a

820
00:35:17,570 --> 00:35:16,200
supernova and you can study all the

821
00:35:21,200 --> 00:35:17,580
chemical elements that come out of it

822
00:35:23,450 --> 00:35:21,210
from the periodic table and this that's

823
00:35:24,890 --> 00:35:23,460
usually if you can study all the stuff

824
00:35:27,500 --> 00:35:24,900
with Kepler you can really get a handle

825
00:35:30,170 --> 00:35:27,510
on exactly what this question mark is

826
00:35:32,390 --> 00:35:30,180
what's blowing up over here that's the

827
00:35:37,220 --> 00:35:32,400
real question we want to ask what's the

828
00:35:39,440 --> 00:35:37,230
physics of these explosions and so there

829
00:35:41,540 --> 00:35:39,450
are different explosion models some of

830
00:35:44,210 --> 00:35:41,550
these things we think you know go to

831
00:35:46,970 --> 00:35:44,220
roughly around 1.4 times the mass of our

832
00:35:48,530 --> 00:35:46,980
Sun and then ignite near the center some

833
00:35:51,020 --> 00:35:48,540
of these things we think just sort of

834
00:35:53,000 --> 00:35:51,030
have a burst near the explosion near the

835
00:35:55,550 --> 00:35:53,010
surface and some of these things we

836
00:35:57,590 --> 00:35:55,560
think get super heavy and then become

837
00:35:59,720 --> 00:35:57,600
much more energetic explosions and even

838
00:36:01,040 --> 00:35:59,730

a very you know despite the fact that

839
00:36:03,140 --> 00:36:01,050
the physics here is very different than

840
00:36:05,420 --> 00:36:03,150
that Hollywood movie these explosion

841
00:36:07,310 --> 00:36:05,430
simulations have much the same result

842
00:36:11,990 --> 00:36:07,320
the entire star blows up in a few

843
00:36:14,359 --> 00:36:12,000
seconds if you sort of made a grid of

844
00:36:15,800 --> 00:36:14,369
all of those models different kinds of

845
00:36:17,930 --> 00:36:15,810
progenitor scenarios plus different

846
00:36:20,000 --> 00:36:17,940
kinds of explosion models there's a lot

847
00:36:21,200 --> 00:36:20,010
of different options out here I don't

848
00:36:23,000 --> 00:36:21,210
want you to try to read all of these

849
00:36:25,070 --> 00:36:23,010
what I want you to take away is we

850
00:36:26,570 --> 00:36:25,080
actually have no good idea what is

851
00:36:28,730 --> 00:36:26,580
causing these explosions and what we

852
00:36:30,410 --> 00:36:28,740
want to find is which box here is

853
00:36:33,440 --> 00:36:30,420
actually producing these stars this is

854
00:36:34,730 --> 00:36:33,450
what we want to identify and there's

855
00:36:36,710 --> 00:36:34,740
lots and lots of different options for

856
00:36:38,420 --> 00:36:36,720
these things so when we study these

857
00:36:39,920 --> 00:36:38,430
things from the ground we can find lots

858
00:36:42,170 --> 00:36:39,930
and lots of supernovae off different

859
00:36:44,030 --> 00:36:42,180
kinds so we really want to find for each

860
00:36:45,890 --> 00:36:44,040
one of these groups is there a separate

861
00:36:48,380 --> 00:36:45,900
explosion mechanism that's responsible

862
00:36:50,090 --> 00:36:48,390
is that circle with a question mark

863
00:36:51,500 --> 00:36:50,100

different in each of these cases are

864
00:36:54,890 --> 00:36:51,510
they the same are the different

865
00:36:56,930 --> 00:36:54,900
contributions to each of them and we've

866
00:36:59,180 --> 00:36:56,940
simply not really been able to do that

867
00:37:01,010 --> 00:36:59,190
so far easily from the ground it's just

868
00:37:05,240 --> 00:37:01,020
been too hard because we're not studying

869
00:37:06,510 --> 00:37:05,250
supernovae early enough we have some

870
00:37:08,670 --> 00:37:06,520
idea what might

871
00:37:12,000 --> 00:37:08,680
and some ways to distinguish these

872
00:37:13,770 --> 00:37:12,010
models back in 2010 dan casein said I

873
00:37:15,930 --> 00:37:13,780
was an astronomer UC Berkeley said that

874
00:37:18,450 --> 00:37:15,940
if you have a white dwarf blowing up

875
00:37:20,940 --> 00:37:18,460
near some star like our Sun what you

876
00:37:22,710 --> 00:37:20,950
should see at really early times where

877
00:37:24,930 --> 00:37:22,720
Kepler can look another things can't is

878
00:37:27,510 --> 00:37:24,940
an excess of flux in excess of

879
00:37:29,400 --> 00:37:27,520
brightness from material from that white

880
00:37:32,460 --> 00:37:29,410
dwarf running into the companion star

881
00:37:34,020 --> 00:37:32,470
lighting it up so now that gives us a

882
00:37:35,520 --> 00:37:34,030
way of disentangling these different

883
00:37:37,109 --> 00:37:35,530
progenitor scenarios from each other we

884
00:37:39,590 --> 00:37:37,119
can potentially differentiate these

885
00:37:43,320 --> 00:37:39,600
things if we can look at light curves

886
00:37:48,300 --> 00:37:43,330
early enough which again we can really

887
00:37:49,560 --> 00:37:48,310
only do with Kepler meanwhile back on

888
00:37:51,150 --> 00:37:49,570

earth we're getting a little better in

889
00:37:52,680 --> 00:37:51,160
doing this and so we're getting more and

890
00:37:55,050 --> 00:37:52,690
more confident that some of this picture

891
00:37:58,500 --> 00:37:55,060
is right this we've started to find

892
00:38:00,510 --> 00:37:58,510
supernovae where we have some limits on

893
00:38:03,359 --> 00:38:00,520
what these explosions in our your skin

894
00:38:06,930 --> 00:38:03,369
be so this is an image of 2011 F V which

895
00:38:09,920 --> 00:38:06,940
is a supernova and we know from deep

896
00:38:12,450 --> 00:38:09,930
Hubble imaging here that there's no

897
00:38:14,970 --> 00:38:12,460
companion that's larger than the single

898
00:38:17,070 --> 00:38:14,980
solar mass right so there's nothing that

899
00:38:20,340 --> 00:38:17,080
looks like a big star near a white dwarf

900
00:38:21,480 --> 00:38:20,350
in this case that's already one little

901
00:38:23,609 --> 00:38:21,490
piece of evidence that suggests

902
00:38:25,920 --> 00:38:23,619
something is going on and maybe it's one

903
00:38:28,080 --> 00:38:25,930
scenario and not the other you've seen a

904
00:38:30,000 --> 00:38:28,090
few others we've seen cases where there

905
00:38:32,700 --> 00:38:30,010
does look like there's something at the

906
00:38:34,890 --> 00:38:32,710
site of the explosion before the star

907
00:38:36,720 --> 00:38:34,900
blew up so here's the supernova it's

908
00:38:38,700 --> 00:38:36,730
happening in this case for 2012 Z and

909
00:38:40,530 --> 00:38:38,710
here's the site of the explosion you

910
00:38:42,510 --> 00:38:40,540
could see something faint and fuzzy over

911
00:38:50,280 --> 00:38:42,520
here so we know that there's something

912
00:38:51,870 --> 00:38:50,290
there we're not sure what it is there's

913
00:38:55,349 --> 00:38:51,880

some other supernova that we've seen

914
00:38:57,180 --> 00:38:55,359
these these sort of UV excesses in we

915
00:38:58,830 --> 00:38:57,190
think but you can look at how rocky this

916
00:39:00,390 --> 00:38:58,840
ground-based data is compared to that

917
00:39:02,940 --> 00:39:00,400
beautiful Kepler data I showed you

918
00:39:04,680 --> 00:39:02,950
there's almost so much noise over here

919
00:39:06,960 --> 00:39:04,690
we can't be sure of this is just a

920
00:39:11,310 --> 00:39:06,970
random spike or if this is actually a

921
00:39:13,560 --> 00:39:11,320
signal of that excess and finally we've

922
00:39:17,380 --> 00:39:13,570
started to see new things this past year

923
00:39:23,890 --> 00:39:17,390
where again this is 2012 Z oops

924
00:39:26,860 --> 00:39:23,900
skip through that we're right in early

925
00:39:28,720 --> 00:39:26,870
times there's a slight bump over here

926
00:39:30,160 --> 00:39:28,730
and it's a slight bump that might say

927
00:39:34,420 --> 00:39:30,170
that there's some kind of companion over

928
00:39:36,520 --> 00:39:34,430
here so for me trying to understand what

929
00:39:40,060 --> 00:39:36,530
the physics of these progenitor systems

930
00:39:43,090 --> 00:39:40,070
is these are all catalyzing clues but

931
00:39:45,070 --> 00:39:43,100
they're not smoking gun so now would

932
00:39:46,690 --> 00:39:45,080
Kepler back in business with the action

933
00:39:49,980 --> 00:39:46,700
wheel fixed effectively by using the Sun

934
00:39:52,480 --> 00:39:49,990
we can go hunt type 1a supernovae right

935
00:39:54,700 --> 00:39:52,490
the first thing we found didn't look

936
00:39:56,950 --> 00:39:54,710
anything like a type 1a supernova that's

937
00:39:59,830 --> 00:39:56,960
a regular type 1a supernova up here in

938
00:40:02,130 --> 00:39:59,840

blue and what we found was something

939
00:40:06,280 --> 00:40:02,140
that did this way different than that

940
00:40:07,690 --> 00:40:06,290
and we were like who ordered this almond

941
00:40:09,970 --> 00:40:07,700
dressed who's in this building led the

942
00:40:12,700 --> 00:40:09,980
analysis of this and it's a supernova

943
00:40:14,680 --> 00:40:12,710
it's in a galaxy there was nothing there

944
00:40:16,360 --> 00:40:14,690
before and then suddenly it pops up and

945
00:40:17,920 --> 00:40:16,370
disappears and it does that in 14 days

946
00:40:19,750 --> 00:40:17,930
it's very inconsistent with all the

947
00:40:21,100 --> 00:40:19,760
other supernovae we've seen it's also

948
00:40:22,960 --> 00:40:21,110
inconsistent with all the other things

949
00:40:25,480 --> 00:40:22,970
that seemed that we know that sort of

950
00:40:28,240 --> 00:40:25,490
rise up and have relatively short time

951
00:40:29,910 --> 00:40:28,250
scales that we've seen so the picture

952
00:40:33,310 --> 00:40:29,920
we've come up with for this thing is

953
00:40:35,200 --> 00:40:33,320
that it's a star that near the end of

954
00:40:37,300 --> 00:40:35,210
its life sort of had a book sort of

955
00:40:40,330 --> 00:40:37,310
baked out of a bunch of gas and then

956
00:40:42,580 --> 00:40:40,340
right before the explosion it did this

957
00:40:44,230 --> 00:40:42,590
and then the explosion happens and it

958
00:40:47,500 --> 00:40:44,240
runs into all this material that it's

959
00:40:49,240 --> 00:40:47,510
it's it's burped out that's lit it up so

960
00:40:51,100 --> 00:40:49,250
Kepler is now teaching us things about

961
00:40:53,170 --> 00:40:51,110
exploding stars that we just didn't even

962
00:40:55,030 --> 00:40:53,180
imagine we learn about initially we

963
00:40:58,240 --> 00:40:55,040

never imagined something like this thing

964
00:41:00,600 --> 00:40:58,250
like KSN 20:59 it was just something

965
00:41:05,350 --> 00:41:00,610
that happened to be discovered

966
00:41:06,580 --> 00:41:05,360
fortuitously with this experiment but

967
00:41:07,810 --> 00:41:06,590
now we really want to find the things

968
00:41:10,540 --> 00:41:07,820
that we did imagine right we want to

969
00:41:11,950 --> 00:41:10,550
find the this kind of type 1a supernovae

970
00:41:15,490 --> 00:41:11,960
that I have sort of started this talk

971
00:41:17,590 --> 00:41:15,500
telling you about and Kepler has

972
00:41:21,760 --> 00:41:17,600
effectively broken up at the k2 mission

973
00:41:24,430 --> 00:41:21,770
into several sort of a TDM campaigns the

974
00:41:27,130 --> 00:41:24,440
vast majority of these campaigns the

975
00:41:29,170 --> 00:41:27,140
orientation of Kepler with the earth and

976
00:41:31,120 --> 00:41:29,180
the Sun is exactly how I showed you in

977
00:41:33,099 --> 00:41:31,130
that original movie of it going around

978
00:41:36,849 --> 00:41:33,109
in the same direction just at one of

979
00:41:39,039 --> 00:41:36,859
these fields for campaign 16 and 17 they

980
00:41:40,539 --> 00:41:39,049
did something rather different they

981
00:41:43,779 --> 00:41:40,549
flipped the task up the other direction

982
00:41:45,549 --> 00:41:43,789
that's really useful for us because for

983
00:41:47,440 --> 00:41:45,559
all the other campaigns we've only had a

984
00:41:49,930 --> 00:41:47,450
very short window right around Twilight

985
00:41:53,410 --> 00:41:49,940
where we could see something with the

986
00:41:55,059 --> 00:41:53,420
ground that Keppler could also see but

987
00:41:57,579 --> 00:41:55,069
by flipping the telescope over the other

988
00:42:00,609 --> 00:41:57,589

direction in this lovely cartoon

989
00:42:02,109 --> 00:42:00,619
suddenly the earth and Kepler can both

990
00:42:05,069 --> 00:42:02,119
observe the same patch of sky at the

991
00:42:08,049 --> 00:42:05,079
same time and so here in this beautiful

992
00:42:11,170 --> 00:42:08,059
illustration Kepler says hey give me

993
00:42:13,450 --> 00:42:11,180
some spectra and people on earth us can

994
00:42:15,219 --> 00:42:13,460
go point our spectra this and so for

995
00:42:17,130 --> 00:42:15,229
most of last year we would this is what

996
00:42:20,279 --> 00:42:17,140
Armand and I and all of the other people

997
00:42:22,870 --> 00:42:20,289
on this project were involved in hunting

998
00:42:24,819 --> 00:42:22,880
supernovae the Kepler discovered with

999
00:42:26,680 --> 00:42:24,829
from the ground seeing if we could get

1000
00:42:29,799 --> 00:42:26,690
more additional information about it and

1001
00:42:33,160 --> 00:42:29,809
realizing what it was soon

1002
00:42:34,749 --> 00:42:33,170
and so campaign 16 and 17 were focused

1003
00:42:37,660 --> 00:42:34,759
on these extra galactic transients and

1004
00:42:40,719 --> 00:42:37,670
it suddenly became like Christmas

1005
00:42:44,969 --> 00:42:40,729
we had been finding you know sakes and

1006
00:42:48,009 --> 00:42:44,979
supernovae we found 42 in campaign 6070

1007
00:42:51,430 --> 00:42:48,019
it's just tremendous explosion of these

1008
00:42:53,109 --> 00:42:51,440
things suddenly a whole bunch more data

1009
00:42:55,660 --> 00:42:53,119
for us to work with lots more papers to

1010
00:42:57,609 --> 00:42:55,670
read lots more analysis to do and so

1011
00:42:59,680 --> 00:42:57,619
what we did was coordinated follow up

1012
00:43:02,200 --> 00:42:59,690
with many many different telescopes the

1013
00:43:03,940 --> 00:43:02,210

pan-starrs telescope in Hawaii the Dec

1014
00:43:06,640 --> 00:43:03,950
cam instrument down in Chile along with

1015
00:43:07,769 --> 00:43:06,650
Swope small telescopes called the atlas

1016
00:43:10,749 --> 00:43:07,779
telescopes that are designed to actually

1017
00:43:13,059 --> 00:43:10,759
provide a warning if an asteroid is

1018
00:43:14,680 --> 00:43:13,069
headed towards Earth a whole bunch of

1019
00:43:16,809 --> 00:43:14,690
different facilities all of these things

1020
00:43:18,729 --> 00:43:16,819
were coordinated observing the same

1021
00:43:20,109 --> 00:43:18,739
patch of sky the Kepler was observing at

1022
00:43:22,180 --> 00:43:20,119
once this is actually kind of

1023
00:43:23,620 --> 00:43:22,190
unprecedented it's hard to get a whole

1024
00:43:25,779 --> 00:43:23,630
bunch of scientists in the same room and

1025
00:43:27,640 --> 00:43:25,789
get them to agree about anything let

1026
00:43:30,849 --> 00:43:27,650
alone do like dedicate the resources to

1027
00:43:33,130 --> 00:43:30,859
what's doing the same science so this is

1028
00:43:34,839 --> 00:43:33,140
really sort of a model for how to manage

1029
00:43:38,109 --> 00:43:34,849
follow-up with scarce resources like

1030
00:43:39,910 --> 00:43:38,119
Hubble in the future and we found

1031
00:43:41,769 --> 00:43:39,920
interesting things so this was one of

1032
00:43:44,079 --> 00:43:41,779
our interesting objects this is

1033
00:43:45,670 --> 00:43:44,089
supernovae 2018 Oh hatch it's a regular

1034
00:43:47,470 --> 00:43:45,680
type 1s soup

1035
00:43:49,390 --> 00:43:47,480
I was covered by the assassin survey on

1036
00:43:51,970 --> 00:43:49,400
the ground and it was in the kepler

1037
00:43:54,970 --> 00:43:51,980
field and here is a image of that

1038
00:43:57,280 --> 00:43:54,980

supernova and if I click this you'll see

1039
00:44:00,520 --> 00:43:57,290
this animation and near the center here

1040
00:44:02,589 --> 00:44:00,530
you should see this thing get brighter

1041
00:44:04,030 --> 00:44:02,599
and brighter over time that's why the

1042
00:44:06,700 --> 00:44:04,040
supernova is that's what Kepler is

1043
00:44:08,770 --> 00:44:06,710
seeing and we can follow it with other

1044
00:44:10,480 --> 00:44:08,780
instruments from the ground and compare

1045
00:44:12,819 --> 00:44:10,490
it with all sorts of other type 1a

1046
00:44:15,280 --> 00:44:12,829
supernovae at the same time and so we

1047
00:44:18,309 --> 00:44:15,290
can finally say hey this thing looks a

1048
00:44:20,859 --> 00:44:18,319
lot like other supernova or desn't we

1049
00:44:22,809 --> 00:44:20,869
can find the differences and we can look

1050
00:44:25,240 --> 00:44:22,819
at these things really early because we

1051
00:44:26,920 --> 00:44:25,250
have this great Kepler light curve so I

1052
00:44:29,319 --> 00:44:26,930
flipped in this great Kepler light curve

1053
00:44:31,150 --> 00:44:29,329
here's you know I sort of four thousand

1054
00:44:33,160 --> 00:44:31,160
observations across the light curve

1055
00:44:36,309 --> 00:44:33,170
those are individual little measurements

1056
00:44:38,230 --> 00:44:36,319
in gray okay every one of those is an

1057
00:44:41,020 --> 00:44:38,240
image Kepler took if we average them

1058
00:44:43,240 --> 00:44:41,030
together in in bins those are the black

1059
00:44:45,430 --> 00:44:43,250
points but the gratings are our actual

1060
00:44:47,770 --> 00:44:45,440
data and this is tremendous because you

1061
00:44:50,349 --> 00:44:47,780
can look at this and look for very very

1062
00:44:53,230 --> 00:44:50,359
minor differences very very many

1063
00:44:55,750 --> 00:44:53,240

departures from theory theory here is

1064
00:44:57,520 --> 00:44:55,760
what the red line is and you can see the

1065
00:44:59,559 --> 00:44:57,530
observations depart just a little bit

1066
00:45:02,559 --> 00:44:59,569
from it but that's the signal that

1067
00:45:04,690 --> 00:45:02,569
really subtle small departure is the

1068
00:45:07,299 --> 00:45:04,700
signal that we're looking for this is

1069
00:45:11,260 --> 00:45:07,309
one of these potential smoking guns so

1070
00:45:13,510 --> 00:45:11,270
that this supernovae is not a simple

1071
00:45:15,849 --> 00:45:13,520
system that you know is simply two white

1072
00:45:17,289 --> 00:45:15,859
dwarfs near each other this looks like

1073
00:45:19,809 --> 00:45:17,299
the sort of excess we'd see if a

1074
00:45:23,200 --> 00:45:19,819
supernova happen when a white dwarf is

1075
00:45:24,700 --> 00:45:23,210
near a star like our Sun and so this is

1076
00:45:26,950 --> 00:45:24,710
starting to look really good because now

1077
00:45:30,640 --> 00:45:26,960
we have clean data that's a lot more

1078
00:45:33,160 --> 00:45:30,650
convincing we can correct a supernova

1079
00:45:35,380 --> 00:45:33,170
compare it against everything else we'd

1080
00:45:37,809 --> 00:45:35,390
seen from Kepler in the past and the

1081
00:45:40,390 --> 00:45:37,819
single slope persists there's just no

1082
00:45:42,250 --> 00:45:40,400
way this flux excess could have been not

1083
00:45:43,690 --> 00:45:42,260
detected in those previous supernovae

1084
00:45:45,099 --> 00:45:43,700
had it been there so this thing is

1085
00:45:48,309 --> 00:45:45,109
genuinely different than the previous

1086
00:45:49,809 --> 00:45:48,319
supernova that even Kepler had seen and

1087
00:45:52,510 --> 00:45:49,819
so the question now is what the source

1088
00:45:55,150 --> 00:45:52,520

of this excess flux is what is the

1089
00:45:56,650 --> 00:45:55,160
physics of the explosion and so we can

1090
00:45:58,720 --> 00:45:56,660
rule out a whole bunch of models but the

1091
00:45:59,020 --> 00:45:58,730
four that remain are collision with a

1092
00:46:02,020 --> 00:45:59,030
binary

1093
00:46:05,260 --> 00:46:02,030
companion star like a son or it could be

1094
00:46:06,400 --> 00:46:05,270
the mixing of nickel which is produced

1095
00:46:08,890 --> 00:46:06,410
during the explosion of a supernova

1096
00:46:12,280 --> 00:46:08,900
right on its surface or it could be

1097
00:46:14,230 --> 00:46:12,290
interaction like you saw in that in that

1098
00:46:15,670 --> 00:46:14,240
book where the star has given off a

1099
00:46:18,130 --> 00:46:15,680
whole bunch of material right before it

1100
00:46:20,830 --> 00:46:18,140
explodes and it's interacting with that

1101
00:46:22,630 --> 00:46:20,840
material lighting it up or it could be

1102
00:46:25,990 --> 00:46:22,640
two of these stars hitting each other

1103
00:46:27,760 --> 00:46:26,000
and blowing Apollo ones and so those are

1104
00:46:32,820 --> 00:46:27,770
the four explanations we were trying to

1105
00:46:34,990 --> 00:46:32,830
sort of consider in the set of papers

1106
00:46:37,690 --> 00:46:35,000
some of the fit the data are better than

1107
00:46:39,760 --> 00:46:37,700
others and so the the two sort of

1108
00:46:42,610 --> 00:46:39,770
leading models right now that we have

1109
00:46:45,250 --> 00:46:42,620
are the circulation model where a

1110
00:46:47,380 --> 00:46:45,260
supernova is running into another main

1111
00:46:49,750 --> 00:46:47,390
sequence star and lighting something up

1112
00:46:51,400 --> 00:46:49,760
or the surface nickel model which we

1113
00:46:53,500 --> 00:46:51,410

can't really rule out with what data we

1114
00:46:54,970 --> 00:46:53,510
have from just Kepler but we have more

1115
00:46:56,320 --> 00:46:54,980
data than just Kepler of course because

1116
00:46:59,290 --> 00:46:56,330
we can follow it up from the ground and

1117
00:47:01,030 --> 00:46:59,300
so we can look for colors and we can

1118
00:47:03,280 --> 00:47:01,040
sort of look and see which models are

1119
00:47:05,170 --> 00:47:03,290
supported and based on this my sort of

1120
00:47:06,850 --> 00:47:05,180
preference here is that this is sort of

1121
00:47:09,550 --> 00:47:06,860
more close to the collision model than

1122
00:47:11,410 --> 00:47:09,560
any of the others there's still some

1123
00:47:13,870 --> 00:47:11,420
debate between the to the surface nickel

1124
00:47:15,640 --> 00:47:13,880
team and the collision team but we've

1125
00:47:17,680 --> 00:47:15,650
narrowed down that grid of possible

1126
00:47:20,350 --> 00:47:17,690
models from several different options to

1127
00:47:22,600 --> 00:47:20,360
do that's a whole lot of improvement

1128
00:47:25,810 --> 00:47:22,610
over what we've had in the past from

1129
00:47:27,340 --> 00:47:25,820
just one object there are other objects

1130
00:47:29,920 --> 00:47:27,350
that we're going to work on soon to you

1131
00:47:31,780 --> 00:47:29,930
this is 2018 agk another supernova that

1132
00:47:33,430 --> 00:47:31,790
we see in this is not perfectly reduced

1133
00:47:36,850 --> 00:47:33,440
yet but it seems to have the same little

1134
00:47:40,840 --> 00:47:36,860
excess of flux down here that we think

1135
00:47:42,820 --> 00:47:40,850
might signify that this too is a star as

1136
00:47:45,700 --> 00:47:42,830
a white dwarf star around a star like

1137
00:47:48,340 --> 00:47:45,710
our Sun that's blowing up and teasing

1138
00:47:50,680 --> 00:47:48,350

out this this really small signature is

1139
00:47:52,660 --> 00:47:50,690
going to be work for the next few months

1140
00:47:55,600 --> 00:47:52,670
for me we're still working on sort of

1141
00:47:57,130 --> 00:47:55,610
removing these these artifacts and

1142
00:47:59,380 --> 00:47:57,140
signatures in the data and some of these

1143
00:48:00,760 --> 00:47:59,390
actually come from how Kepler observes I

1144
00:48:03,280 --> 00:48:00,770
told you we were balancing this thing

1145
00:48:05,380 --> 00:48:03,290
out effectively with sunlight and that

1146
00:48:07,660 --> 00:48:05,390
doesn't work perfectly if you actually

1147
00:48:09,430 --> 00:48:07,670
look at a star with Kepler it bounces

1148
00:48:12,130 --> 00:48:09,440
around because the solar pressure is not

1149
00:48:13,030 --> 00:48:12,140
constant over time and you can see all

1150
00:48:13,990 --> 00:48:13,040
sorts of instrum

1151
00:48:15,220 --> 00:48:14,000
a lot of folks could see a little

1152
00:48:17,320 --> 00:48:15,230
asteroid or something move through the

1153
00:48:19,930 --> 00:48:17,330
frame over here you can see cosmic rays

1154
00:48:21,310 --> 00:48:19,940
all of these complex effects all have to

1155
00:48:24,520 --> 00:48:21,320
be accounted for in the data when we

1156
00:48:26,860 --> 00:48:24,530
analyze things with Kepler but while

1157
00:48:29,500 --> 00:48:26,870
this is a complicated problem teasing

1158
00:48:31,330 --> 00:48:29,510
out these these delicate signals from

1159
00:48:32,530 --> 00:48:31,340
the data is something we can do and

1160
00:48:35,170 --> 00:48:32,540
something we're getting better and

1161
00:48:37,420 --> 00:48:35,180
better with doing but the theories where

1162
00:48:39,820 --> 00:48:37,430
sort of story the happy story sort of

1163
00:48:41,680 --> 00:48:39,830

comes to an end a little bit Kepler is

1164
00:48:43,360 --> 00:48:41,690
dying it's running out of fuel it's on

1165
00:48:46,570 --> 00:48:43,370
its last legs this will almost certainly

1166
00:48:48,910 --> 00:48:46,580
be its last campaign campaign twenty and

1167
00:48:50,440 --> 00:48:48,920
it probably will not finish it they will

1168
00:48:52,120 --> 00:48:50,450
have to probably stop taking

1169
00:48:55,630 --> 00:48:52,130
observations and save the data from the

1170
00:48:58,330 --> 00:48:55,640
telescope before it runs out of fuel but

1171
00:49:00,160 --> 00:48:58,340
the good news is that we have more

1172
00:49:03,040 --> 00:49:00,170
telescopes of the way this is sort of a

1173
00:49:04,600 --> 00:49:03,050
timeline effectively F of NASA's expert

1174
00:49:06,970 --> 00:49:04,610
at Ellis copse and Kepler's over here

1175
00:49:09,010 --> 00:49:06,980
but it's already been succeeded by tests

1176
00:49:10,900 --> 00:49:09,020
just the next great except an admission

1177
00:49:12,790 --> 00:49:10,910
from NASA and it's going to be followed

1178
00:49:14,860 --> 00:49:12,800
by the Webb telescope or model of which

1179
00:49:19,270 --> 00:49:14,870
is over there and in the future sort of

1180
00:49:22,570 --> 00:49:19,280
in 2025 ish w first mission and Tess is

1181
00:49:24,010 --> 00:49:22,580
is an incredible thing where Kepler was

1182
00:49:27,280 --> 00:49:24,020
setting in a small patch of sky at a

1183
00:49:30,900 --> 00:49:27,290
given amount of time into e ups in two

1184
00:49:33,820 --> 00:49:30,910
years tests will cover the entire sky

1185
00:49:34,570 --> 00:49:33,830
we're really high cadence that's pretty

1186
00:49:36,910 --> 00:49:34,580
impressive

1187
00:49:38,770 --> 00:49:36,920
it doesn't go nearly is deepest Kepler

1188
00:49:41,740 --> 00:49:38,780

we can't see as far out into our

1189
00:49:43,870 --> 00:49:41,750
universe as we do but simply because of

1190
00:49:46,090 --> 00:49:43,880
the amount of area it covers at any time

1191
00:49:48,400 --> 00:49:46,100
it will effectively be a machine at

1192
00:49:50,290 --> 00:49:48,410
finding these supernovae and so we'll go

1193
00:49:51,610 --> 00:49:50,300
from probably a handful of objects where

1194
00:49:53,710 --> 00:49:51,620
we can tease out the signal and

1195
00:49:56,080 --> 00:49:53,720
understand the physics of the supernova

1196
00:49:57,640 --> 00:49:56,090
to hundreds of these things and so we

1197
00:50:00,370 --> 00:49:57,650
expect we'll also find things that we've

1198
00:50:06,820 --> 00:50:00,380
just not imagined before in the data and

1199
00:50:08,470 --> 00:50:06,830
that'll be kind of an exciting time so I

1200
00:50:10,350 --> 00:50:08,480
sort of want to wrap things up a little

1201
00:50:12,610 --> 00:50:10,360
bit and take questions from you folks

1202
00:50:14,170 --> 00:50:12,620
Kepler has been a really amazing

1203
00:50:16,390 --> 00:50:14,180
facility for us we've been finding all

1204
00:50:18,690 --> 00:50:16,400
sorts of things that blow up stuff that

1205
00:50:21,220 --> 00:50:18,700
effectively made me an astronomer and

1206
00:50:24,430 --> 00:50:21,230
lit up my eyes as a kid all of these

1207
00:50:27,040 --> 00:50:24,440
exciting explosions we've seen these

1208
00:50:28,870 --> 00:50:27,050
excess flux in a couple of objects

1209
00:50:30,250 --> 00:50:28,880
we've seen other objects that don't have

1210
00:50:32,800 --> 00:50:30,260
it we have seen things that we just

1211
00:50:35,380 --> 00:50:32,810
didn't imagine this for example is a

1212
00:50:37,990 --> 00:50:35,390
light curve for an object my student is

1213
00:50:40,270 --> 00:50:38,000

working on and it's entire time scale is

1214
00:50:42,250 --> 00:50:40,280
about 20 days it rises and falls much

1215
00:50:44,109 --> 00:50:42,260
much faster than the supernovae and we

1216
00:50:46,300 --> 00:50:44,119
know nothing like it we've never seen

1217
00:50:49,240 --> 00:50:46,310
anything that behaves like this it's

1218
00:50:51,099 --> 00:50:49,250
just a mystery as to what it is that's

1219
00:50:53,410 --> 00:50:51,109
just cool its discovery space for us

1220
00:50:55,150 --> 00:50:53,420
well we're learning about explosions

1221
00:50:56,770 --> 00:50:55,160
that Keppler himself could never have

1222
00:51:01,599 --> 00:50:56,780
imagined but these things are so rare

1223
00:51:02,740 --> 00:51:01,609
that he never would have seen them and

1224
00:51:05,680 --> 00:51:02,750
we're finding things earlier and earlier

1225
00:51:07,780 --> 00:51:05,690
than we've ever managed to before along

1226
00:51:09,760 --> 00:51:07,790
with experiments like Lego which

1227
00:51:12,040 --> 00:51:09,770
understand not just photons but

1228
00:51:14,530 --> 00:51:12,050
gravitational waves and ice cubes that

1229
00:51:16,780 --> 00:51:14,540
are studying neutrinos we're really

1230
00:51:18,940 --> 00:51:16,790
learning about things across the entire

1231
00:51:20,530 --> 00:51:18,950
electromagnetic spectrum we're no longer

1232
00:51:22,630 --> 00:51:20,540
just looking at the sort of beautiful

1233
00:51:25,290 --> 00:51:22,640
visible light images like this Hubble

1234
00:51:29,740 --> 00:51:25,300
picture you got of the bubble nebula

1235
00:51:32,020 --> 00:51:29,750
right when you walk in and this is

1236
00:51:33,609 --> 00:51:32,030
really cool because what will happen is

1237
00:51:36,880 --> 00:51:33,619
that will understand the progenitor

1238
00:51:38,200 --> 00:51:36,890

systems and physics of these supernovae

1239
00:51:40,810 --> 00:51:38,210
which will in turn help us understand

1240
00:51:42,970 --> 00:51:40,820
and explain and improve our models of

1241
00:51:45,640 --> 00:51:42,980
supernovae better and so in a few years

1242
00:51:48,250 --> 00:51:45,650
if you come back here I hope to not have

1243
00:51:50,170 --> 00:51:48,260
any of these question marks on our

1244
00:51:53,020 --> 00:51:50,180
slides anymore I hope to not have any

1245
00:51:55,150 --> 00:51:53,030
circles where we don't understand what

1246
00:51:57,700 --> 00:51:55,160
the origin of a particular stars

1247
00:51:59,950 --> 00:51:57,710
explosion is I hope we'll be able to

1248
00:52:02,349 --> 00:51:59,960
fill that entire thing out and tell you

1249
00:52:04,839 --> 00:52:02,359
here is how this star lived here is how

1250
00:52:06,690 --> 00:52:04,849
the star died and there's more to come

1251
00:52:09,280 --> 00:52:06,700
because there's so many more exciting

1252
00:52:11,500 --> 00:52:09,290
missions in the near future and without

1253
00:52:21,070 --> 00:52:11,510
a questions

1254
00:52:28,520 --> 00:52:25,580
all right can we have the microphone

1255
00:52:30,800 --> 00:52:28,530
cube coming down yes the microphone cube

1256
00:52:33,320 --> 00:52:30,810
is coming down all right who's got a

1257
00:52:43,820 --> 00:52:33,330
question for us you can do it without

1258
00:52:46,130 --> 00:52:43,830
the microphone cube I'll repeat it when

1259
00:52:55,340 --> 00:52:46,140
these supernovas blow up what happens

1260
00:52:58,280 --> 00:52:55,350
after that you know in the stream it

1261
00:53:01,340 --> 00:52:58,290
just dissipates what happens this is a

1262
00:53:03,380 --> 00:53:01,350
beautiful question so if you look at

1263
00:53:05,360 --> 00:53:03,390

that image of the bubble nebula that you

1264
00:53:07,940 --> 00:53:05,370
got as you walked in that's hot what

1265
00:53:09,230 --> 00:53:07,950
that's what remains from a supernova

1266
00:53:12,680 --> 00:53:09,240
Ashley can you put me one of those

1267
00:53:14,830 --> 00:53:12,690
things up one of these this is kind of

1268
00:53:17,450 --> 00:53:14,840
what it looks like for a supernova

1269
00:53:19,760 --> 00:53:17,460
several hundreds of years after the

1270
00:53:22,490 --> 00:53:19,770
explosions happened and so what you have

1271
00:53:24,140 --> 00:53:22,500
is this smorgasbord of material that was

1272
00:53:26,480 --> 00:53:24,150
produced in the explosion of the stars

1273
00:53:29,360 --> 00:53:26,490
all the heavy elements all the way up to

1274
00:53:30,740 --> 00:53:29,370
iron on the periodic table and it's it's

1275
00:53:32,660 --> 00:53:30,750
absolutely true that supernovae are

1276
00:53:34,940 --> 00:53:32,670
destructive forces if there are planets

1277
00:53:37,580 --> 00:53:34,950
around that curve and it blew up they

1278
00:53:39,200 --> 00:53:37,590
aren't there anymore but on the other

1279
00:53:40,850 --> 00:53:39,210
hand they are also creative forces

1280
00:53:43,430 --> 00:53:40,860
because these things are effectively

1281
00:53:45,650 --> 00:53:43,440
engines producing the periodic table

1282
00:53:47,570 --> 00:53:45,660
you're absolutely right they enrich the

1283
00:53:49,910 --> 00:53:47,580
galaxies they enrich the surrounding

1284
00:53:52,010 --> 00:53:49,920
environment the next generation of stars

1285
00:53:53,750 --> 00:53:52,020
that will be formed would be from it

1286
00:53:56,660 --> 00:53:53,760
will incorporate material from the

1287
00:53:59,060 --> 00:53:56,670
supernova they will have more metal for

1288
00:54:01,490 --> 00:53:59,070

example and stars like our Sun which I

1289
00:54:03,290 --> 00:54:01,500
could post mostly of hydrogen have

1290
00:54:04,970 --> 00:54:03,300
slightly different properties and this

1291
00:54:11,930 --> 00:54:04,980
is effectively the universe recycling a

1292
00:54:20,480 --> 00:54:11,940
little bit that's what the wife of the

1293
00:54:25,380 --> 00:54:22,770
not about the type of the explosion our

1294
00:54:27,660 --> 00:54:25,390
son will have so star like that son is

1295
00:54:29,700 --> 00:54:27,670
not going to have an explosive fiery

1296
00:54:32,520 --> 00:54:29,710
death it's it's a little bit more wimpy

1297
00:54:36,090 --> 00:54:32,530
it's going to sort of puff up and become

1298
00:54:38,010 --> 00:54:36,100
a red giant star its size will be a

1299
00:54:40,650 --> 00:54:38,020
little less than the orbit of Jupiter so

1300
00:54:41,940 --> 00:54:40,660
all the inner planets will be cooked but

1301
00:54:43,170 --> 00:54:41,950
this will be in about five billion years

1302
00:54:50,760 --> 00:54:43,180
you don't worry about your property

1303
00:54:53,250 --> 00:54:50,770
values and once that that puffy red

1304
00:54:56,160 --> 00:54:53,260
giant phase is over what's left at the

1305
00:54:57,480 --> 00:54:56,170
center of the star is its core this

1306
00:55:00,030 --> 00:54:57,490
white dwarf the sort of thing that

1307
00:55:03,270 --> 00:55:00,040
becomes a supernova of type 1a

1308
00:55:05,670 --> 00:55:03,280
potentially that white dwarf if nothing

1309
00:55:07,920 --> 00:55:05,680
happens to it if it sits there by itself

1310
00:55:10,170 --> 00:55:07,930
it will simply cool for the rest of the

1311
00:55:11,790 --> 00:55:10,180
lifetime of the universe what when

1312
00:55:14,700 --> 00:55:11,800
interesting things happen is when that

1313
00:55:18,320 --> 00:55:14,710

white dwarf starts to get mass from some

1314
00:55:20,760 --> 00:55:18,330
other companion whether another star or

1315
00:55:21,750 --> 00:55:20,770
another white wolf and that's exactly

1316
00:55:26,820 --> 00:55:21,760
the kind of scenario we're trying to

1317
00:55:30,360 --> 00:55:26,830
figure out hey other questions yes in

1318
00:55:32,910 --> 00:55:30,370
the center there catch that's the

1319
00:55:35,190 --> 00:55:32,920
microphone there 18 and 17 you pointed

1320
00:55:38,820 --> 00:55:35,200
the Keppler the other direction and

1321
00:55:42,360 --> 00:55:38,830
coordinated with earth and I don't know

1322
00:55:44,010 --> 00:55:42,370
seven or eight more times observations

1323
00:55:45,390 --> 00:55:44,020
in supernovae is that because of the

1324
00:55:46,710 --> 00:55:45,400
coordination with the earth or because

1325
00:55:51,990 --> 00:55:46,720
it was pointing the other way well

1326
00:55:53,490 --> 00:55:52,000
exactly so so the question was that did

1327
00:55:54,780 --> 00:55:53,500
we find more of these supernovae because

1328
00:55:55,320 --> 00:55:54,790
we were pointing the telescope in the

1329
00:55:57,920 --> 00:55:55,330
other direction

1330
00:56:00,240 --> 00:55:57,930
the answer is exactly yes when it's

1331
00:56:02,250 --> 00:56:00,250
forward-facing in the configuration I

1332
00:56:04,740 --> 00:56:02,260
showed you there's only a short window

1333
00:56:07,550 --> 00:56:04,750
around Twilight morning and evening

1334
00:56:09,930 --> 00:56:07,560
Twilight when observers on the ground

1335
00:56:12,450 --> 00:56:09,940
can look at the same area of the sky the

1336
00:56:14,400 --> 00:56:12,460
Kepler is looking after that the field

1337
00:56:16,230 --> 00:56:14,410
sets and so it's below the horizon

1338
00:56:18,600 --> 00:56:16,240

we can't go point our telescopes at it

1339
00:56:20,430 --> 00:56:18,610
at night that doesn't make for a very

1340
00:56:22,470 --> 00:56:20,440
large window with which to go find

1341
00:56:25,560 --> 00:56:22,480
supernovae when you do it in the

1342
00:56:28,050 --> 00:56:25,570
opposite geometry then suddenly the

1343
00:56:30,180 --> 00:56:28,060
field that Kepler is pointing at is also

1344
00:56:31,740 --> 00:56:30,190
available to be observed from the ground

1345
00:56:34,650 --> 00:56:31,750
for basically the entire

1346
00:56:39,270 --> 00:56:34,660
it's dark and because we have more time

1347
00:56:40,380 --> 00:56:39,280
to find things we find more things all

1348
00:56:44,700 --> 00:56:40,390
right we've got a question from online

1349
00:56:46,440 --> 00:56:44,710
I'm gonna ask it says is there any

1350
00:56:49,349 --> 00:56:46,450
neutrino emission from a supernova

1351
00:56:52,950 --> 00:56:49,359
explosion oh that is an interesting and

1352
00:56:56,480 --> 00:56:52,960
research question so the answer is there

1353
00:56:59,880 --> 00:56:56,490
has been we know of at least one object

1354
00:57:02,670 --> 00:56:59,890
supernova 1987a in Large Magellanic

1355
00:57:05,430 --> 00:57:02,680
Cloud that emitted some neutrinos they

1356
00:57:06,660 --> 00:57:05,440
have to be very powerful explosions the

1357
00:57:09,750 --> 00:57:06,670
kind of explosions that create these

1358
00:57:11,520 --> 00:57:09,760
neutrinos are almost certainly that not

1359
00:57:14,130 --> 00:57:11,530
the type 1a supernova I was looking at

1360
00:57:15,599 --> 00:57:14,140
but much more analogous to the collapse

1361
00:57:18,589 --> 00:57:15,609
of those massive stars like Krypton

1362
00:57:21,450 --> 00:57:18,599
exploding the Sun of Krypton exploding

1363
00:57:23,760 --> 00:57:21,460

those sort of events will produce entry

1364
00:57:25,559 --> 00:57:23,770
knows there's a lot of research to try

1365
00:57:28,770 --> 00:57:25,569
to find these things that are detectors

1366
00:57:30,960 --> 00:57:28,780
that are essentially giant rats of heavy

1367
00:57:33,720 --> 00:57:30,970
water and sodium with photomultiplier

1368
00:57:35,819 --> 00:57:33,730
tubes all around them both in Antarctica

1369
00:57:37,500 --> 00:57:35,829
and Japan all over the place to try to

1370
00:57:39,359 --> 00:57:37,510
find these signals but we've not been

1371
00:57:42,480 --> 00:57:39,369
able to find very many of these things

1372
00:57:43,890 --> 00:57:42,490
they're really hard to tease out because

1373
00:57:47,760 --> 00:57:43,900
we also just don't find that many

1374
00:57:57,870 --> 00:57:47,770
supernovae near us it's probably for the

1375
00:57:59,430 --> 00:57:57,880
best really given the age of the

1376
00:58:02,910 --> 00:57:59,440
universe something thirteen or fourteen

1377
00:58:06,930 --> 00:58:02,920
billion years are there likely to be

1378
00:58:10,770 --> 00:58:06,940
more supernovae in the future or is the

1379
00:58:12,420 --> 00:58:10,780
kind of steady state this is a beautiful

1380
00:58:14,819 --> 00:58:12,430
question that's and that has a

1381
00:58:17,640 --> 00:58:14,829
complicated answer they're the kinds of

1382
00:58:20,880 --> 00:58:17,650
supernovae and rates change as a

1383
00:58:23,069 --> 00:58:20,890
function of the age of the universe so

1384
00:58:26,160 --> 00:58:23,079
as we go further and further back in

1385
00:58:27,510 --> 00:58:26,170
time you expect fewer and fewer type 1a

1386
00:58:31,020 --> 00:58:27,520
supernovae the universe hasn't had

1387
00:58:33,630 --> 00:58:31,030
enough time for stars to grow or die

1388
00:58:35,700 --> 00:58:33,640

form white dwarfs and have like many

1389
00:58:38,130 --> 00:58:35,710
type 1a supernovae but on the other hand

1390
00:58:40,440 --> 00:58:38,140
you have more and more massive stars the

1391
00:58:42,000 --> 00:58:40,450
further back in time you look and so you

1392
00:58:45,039 --> 00:58:42,010
have more core collapse explosions

1393
00:58:46,569 --> 00:58:45,049
moving this far

1394
00:58:48,819 --> 00:58:46,579
into the future the opposite thing

1395
00:58:50,470 --> 00:58:48,829
happens you will expect more type 1a

1396
00:58:52,529 --> 00:58:50,480
supernovae because the universe is older

1397
00:58:55,839 --> 00:58:52,539
and you have more of these white walls

1398
00:58:57,160 --> 00:58:55,849
but and you'll expect fewer collapse

1399
00:58:59,499 --> 00:58:57,170
explosions because the universe is just

1400
00:59:03,519 --> 00:58:59,509
producing less of these really massive

1401
00:59:05,349 --> 00:59:03,529
stars but we're talking about changes

1402
00:59:07,239 --> 00:59:05,359
over billions of years these are hard to

1403
00:59:09,430 --> 00:59:07,249
measure on sort of small time scales

1404
00:59:10,870 --> 00:59:09,440
like millions of years so it is really

1405
00:59:12,099 --> 00:59:10,880
very far in the future we're talking

1406
00:59:14,589 --> 00:59:12,109
about where we will see a significant

1407
00:59:16,150 --> 00:59:14,599
difference the the numbers of these

1408
00:59:17,859 --> 00:59:16,160
things that we find are actually quite

1409
00:59:21,099 --> 00:59:17,869
uncertain and so these this is an active

1410
00:59:23,410 --> 00:59:21,109
area of study okay let's get the

1411
00:59:26,349 --> 00:59:23,420
microphone up there I um I was wondering

1412
00:59:27,670 --> 00:59:26,359
uh do we have any predictive ways of

1413
00:59:29,499 --> 00:59:27,680

figuring out whether a particular star

1414
00:59:31,089 --> 00:59:29,509
is going supernova I mean obviously

1415
00:59:33,460 --> 00:59:31,099
maybe we can be like oh yeah and a

1416
00:59:37,059 --> 00:59:33,470
couple million years but anything within

1417
00:59:38,019 --> 00:59:37,069
our lifetimes so sorry and I also wanted

1418
00:59:40,299 --> 00:59:38,029
to ask what would happen if the

1419
00:59:44,620 --> 00:59:40,309
supernova did happen near us like Alpha

1420
00:59:46,630 --> 00:59:44,630
Centauri or something all right so all

1421
00:59:49,509 --> 00:59:46,640
our particular ways of looking for

1422
00:59:52,180 --> 00:59:49,519
supernova events in some cases yeah we

1423
00:59:55,210 --> 00:59:52,190
sort of if you look up in in the night

1424
00:59:57,130 --> 00:59:55,220
sky today and you go look at the Orion

1425
00:59:59,559 --> 00:59:57,140
constellation you'll see a style called

1426
01:00:02,620 --> 00:59:59,569
beatlejuice beatlejuice is a red giant

1427
01:00:04,059 --> 01:00:02,630
star it'll die in its in some point of

1428
01:00:06,700 --> 01:00:04,069
time for the other we know it'll extend

1429
01:00:09,789 --> 01:00:06,710
its life as a supernova the problem is

1430
01:00:11,589 --> 01:00:09,799
we just don't know when that will be it

1431
01:00:12,940 --> 01:00:11,599
might be a million years it might be

1432
01:00:15,670 --> 01:00:12,950
tomorrow it might be several billion

1433
01:00:17,019 --> 01:00:15,680
years this is a problem if you sort of

1434
01:00:18,519 --> 01:00:17,029
want to write your PhD thesis because

1435
01:00:18,819 --> 01:00:18,529
you only have a few of these years to do

1436
01:00:23,170 --> 01:00:18,829
it

1437
01:00:24,849 --> 01:00:23,180
and similarly people have looked for

1438
01:00:26,979 --> 01:00:24,859

sort of white dwarfs which are around

1439
01:00:28,809 --> 01:00:26,989
other systems and look to be sort of in

1440
01:00:30,370 --> 01:00:28,819
decaying orbits where they look like

1441
01:00:31,599 --> 01:00:30,380
they might merge and have an explosion

1442
01:00:35,170 --> 01:00:31,609
but none of these systems are sort of

1443
01:00:37,620 --> 01:00:35,180
easily study about on timescales that

1444
01:00:39,640 --> 01:00:37,630
are comparable to human lifetimes so

1445
01:00:41,920 --> 01:00:39,650
what we do is the scattershot approach

1446
01:00:44,229 --> 01:00:41,930
where instead we look in lots and lots

1447
01:00:47,019 --> 01:00:44,239
of millions of galaxies and try to find

1448
01:00:50,200 --> 01:00:47,029
what blew up instead as for what will

1449
01:00:52,329 --> 01:00:50,210
happen if Alpha Centauri blew up near us

1450
01:00:52,870 --> 01:00:52,339
not whole lot it's actually pretty far

1451
01:00:54,789 --> 01:00:52,880
away

1452
01:00:57,640 --> 01:00:54,799
so Proxima Centuri is is about four

1453
01:00:58,960 --> 01:00:57,650
ideas away we you

1454
01:01:00,309 --> 01:00:58,970
really worrying about and you'd see

1455
01:01:02,980 --> 01:01:00,319
something cool in the night sky for a

1456
01:01:07,990 --> 01:01:02,990
while but it's far enough away that it's

1457
01:01:10,599 --> 01:01:08,000
not a huge impact anytime soon you

1458
01:01:12,970 --> 01:01:10,609
mentioned the subject of neutrinos came

1459
01:01:16,029 --> 01:01:12,980
up is that the reference to ice cube up

1460
01:01:18,099 --> 01:01:16,039
there yep so the ice cube experiment is

1461
01:01:19,859 --> 01:01:18,109
has a whole bunch of people at the

1462
01:01:23,140 --> 01:01:19,869
University of Maryland involved in it

1463
01:01:25,900 --> 01:01:23,150

and so we're really excited about these

1464
01:01:27,430 --> 01:01:25,910
things because they're really a channel

1465
01:01:29,519 --> 01:01:27,440
of physics that we've not been able to

1466
01:01:32,769 --> 01:01:29,529
probe easily in the past we've had

1467
01:01:35,109 --> 01:01:32,779
telescopes like Hubble and JWST in the

1468
01:01:36,970 --> 01:01:35,119
future that look at photons but

1469
01:01:39,490 --> 01:01:36,980
neutrinos are effectively giving us a

1470
01:01:41,019 --> 01:01:39,500
different story of physics and so we're

1471
01:01:43,690 --> 01:01:41,029
really excited about what we can learn

1472
01:01:48,069 --> 01:01:43,700
as these facilities like ice cube get

1473
01:01:49,390 --> 01:01:48,079
more and more sophisticated so we've got

1474
01:01:52,269 --> 01:01:49,400
a question on line I'm trying to

1475
01:01:55,359 --> 01:01:52,279
paraphrase it can we measure a star's

1476
01:02:00,579 --> 01:01:55,369
rate of decay into a white dwarf or its

1477
01:02:01,930 --> 01:02:00,589
transition from stable to unstable can

1478
01:02:04,569 --> 01:02:01,940
we measure the spin looked at if we

1479
01:02:06,010 --> 01:02:04,579
looked at you know the sun's gonna go

1480
01:02:09,609 --> 01:02:06,020
white dwarf in you know five billion

1481
01:02:13,630 --> 01:02:09,619
years right now or even measures if it's

1482
01:02:18,089 --> 01:02:13,640
gonna go we think we've seen stars

1483
01:02:21,190 --> 01:02:18,099
evolve significantly in a very few cases

1484
01:02:24,069 --> 01:02:21,200
there are stars that are already in a

1485
01:02:27,819 --> 01:02:24,079
part of space called the instability

1486
01:02:32,349 --> 01:02:27,829
scrip scrip and these stars effectively

1487
01:02:36,269 --> 01:02:32,359
are sort of done burning fuel for the

1488
01:02:38,950 --> 01:02:36,279

most part they're slowly moving towards

1489
01:02:40,720 --> 01:02:38,960
these other phases of stellar level you

1490
01:02:44,289 --> 01:02:40,730
shouldn't be the red giant or a white

1491
01:02:47,140 --> 01:02:44,299
dwarf and and because these things are

1492
01:02:49,029 --> 01:02:47,150
stable they do show pulsations over time

1493
01:02:51,700 --> 01:02:49,039
they show all sorts of unpredictable

1494
01:02:54,519 --> 01:02:51,710
behavior and so that kind of thing has

1495
01:02:58,120 --> 01:02:54,529
been studied but have we seen a single

1496
01:03:01,029 --> 01:02:58,130
star evolve from burning hydrogen to

1497
01:03:02,559 --> 01:03:01,039
running out of fuel becoming a red giant

1498
01:03:05,380 --> 01:03:02,569
and then becoming a way to offer and oh

1499
01:03:07,779 --> 01:03:05,390
that that would be several billion years

1500
01:03:09,579 --> 01:03:07,789
all right we see the most massive stars

1501
01:03:11,360 --> 01:03:09,589
like in a car right you know over the

1502
01:03:13,760 --> 01:03:11,370
past 150 years it's had lots

1503
01:03:16,640 --> 01:03:13,770
per site and such so the very massive

1504
01:03:21,850 --> 01:03:16,650
stars we see things but that the boring

1505
01:03:21,860 --> 01:03:29,140
other questions here I'm going up there

1506
01:03:36,890 --> 01:03:34,820
cool what kind of things can you predict

1507
01:03:40,310 --> 01:03:36,900
about stars as the metallicity of the

1508
01:03:42,320 --> 01:03:40,320
stars increase and so you start ending

1509
01:03:44,330 --> 01:03:42,330
up with very massive stars that are

1510
01:03:46,040 --> 01:03:44,340
going to go supernova but they've got a

1511
01:03:50,150 --> 01:03:46,050
lot more metal than the stars in the

1512
01:03:51,140 --> 01:03:50,160
current era do so we this is a hard

1513
01:03:55,070 --> 01:03:51,150

question without getting a whole bunch

1514
01:03:56,510 --> 01:03:55,080
of stellar astrophysics maybe the right

1515
01:03:58,400 --> 01:03:56,520
answer to this question is that I find

1516
01:04:02,150 --> 01:03:58,410
you after this talk and we shot because

1517
01:04:04,940 --> 01:04:02,160
this is lots of properties of stars

1518
01:04:06,980 --> 01:04:04,950
change the temperature surface

1519
01:04:08,690 --> 01:04:06,990
properties sort of whether they have

1520
01:04:10,220 --> 01:04:08,700
sunspots or not there's so many

1521
01:04:12,740 --> 01:04:10,230
different properties of stars are

1522
01:04:14,240 --> 01:04:12,750
effectively a impacted by whether they

1523
01:04:16,310 --> 01:04:14,250
have just a small amount of metal in

1524
01:04:18,620 --> 01:04:16,320
them and so as the metallicity of stars

1525
01:04:20,420 --> 01:04:18,630
changed lots of different things change

1526
01:04:24,050 --> 01:04:20,430
at the same time and it's a really

1527
01:04:26,060 --> 01:04:24,060
complicated picture to try to explain

1528
01:04:28,010 --> 01:04:26,070
all of that but you know the answer is

1529
01:04:35,830 --> 01:04:28,020
we see these things we see it has an

1530
01:04:42,920 --> 01:04:39,620
so you said that the supernovae are the

1531
01:04:45,710 --> 01:04:42,930
source of many the minerals in the

1532
01:04:49,550 --> 01:04:45,720
universe and the earth is made of these

1533
01:04:52,910 --> 01:04:49,560
elements so do we have any guess when

1534
01:04:54,740 --> 01:04:52,920
and where from the elements that where

1535
01:04:58,100 --> 01:04:54,750
the supernova was that produced the

1536
01:04:59,450 --> 01:04:58,110
elements that comprise the earth not not

1537
01:05:03,830 --> 01:04:59,460
a good guess at all all right

1538
01:05:06,500 --> 01:05:03,840

the the our galaxy our solar system is

1539
01:05:08,830 --> 01:05:06,510
is several billion years old

1540
01:05:10,880 --> 01:05:08,840
the earth is about 4.3 billion years old

1541
01:05:12,410 --> 01:05:10,890
supernovae that would have gone off in

1542
01:05:14,000 --> 01:05:12,420
our galaxy before that we obviously

1543
01:05:15,890 --> 01:05:14,010
can't study and tell you anything about

1544
01:05:18,530 --> 01:05:15,900
but they'd have had to happen before

1545
01:05:21,200 --> 01:05:18,540
that for all of these metals to be

1546
01:05:24,350 --> 01:05:21,210
around now they get the Galaxy itself

1547
01:05:26,300 --> 01:05:24,360
has a dynamical time scale it involves

1548
01:05:28,580 --> 01:05:26,310
changes stars move around and that

1549
01:05:30,260 --> 01:05:28,590
timescales much shorter so there's

1550
01:05:32,750 --> 01:05:30,270
almost no way to back back out

1551
01:05:35,450 --> 01:05:32,760
effectively what star exploded as a

1552
01:05:38,060 --> 01:05:35,460
supernova to effectively seed the earth

1553
01:05:39,859 --> 01:05:38,070
with its it's primordial elements we

1554
01:05:41,450 --> 01:05:39,869
can't ever tell that in fact the last

1555
01:05:44,510 --> 01:05:41,460
supernova we've seen in our galaxy with

1556
01:05:45,920 --> 01:05:44,520
our that was visibly observed in in the

1557
01:05:52,340 --> 01:05:45,930
northern hemisphere was in fact Kepler

1558
01:05:54,410 --> 01:05:52,350
supernova 16 in 1609 yeah and they a

1559
01:05:56,270 --> 01:05:54,420
good thing that keep in mind is our Sun

1560
01:05:58,430 --> 01:05:56,280
has made about eighteen orbits around

1561
01:06:00,980 --> 01:05:58,440
the center of the Milky Way since it was

1562
01:06:03,710 --> 01:06:00,990
born so there's a lot of diffusion and

1563
01:06:07,070 --> 01:06:03,720

things that happens in 18 orbits and so

1564
01:06:09,650 --> 01:06:07,080
the what-what was near us 18 orbits ago

1565
01:06:11,390 --> 01:06:09,660
is not necessarily near us today and of

1566
01:06:13,520 --> 01:06:11,400
course the Galaxy itself is a violent

1567
01:06:15,080 --> 01:06:13,530
place on our Milky Way we've seen

1568
01:06:16,970 --> 01:06:15,090
evidence of it cannibalizing other

1569
01:06:18,859 --> 01:06:16,980
galaxies there's a stream of stars

1570
01:06:20,660 --> 01:06:18,869
called the Sagittarius stream which we

1571
01:06:22,580 --> 01:06:20,670
think is effectively the Milky Way

1572
01:06:25,190 --> 01:06:22,590
eating the stars off of another galaxy

1573
01:06:27,140 --> 01:06:25,200
but a big matter off of it into our own

1574
01:06:29,180 --> 01:06:27,150
and this will eventually happen several

1575
01:06:31,220 --> 01:06:29,190
billions of years into the future with

1576
01:06:34,040 --> 01:06:31,230
our galaxy and Andromeda these things

1577
01:06:35,720 --> 01:06:34,050
will come to a head and and there will

1578
01:06:38,599 --> 01:06:35,730
be stars effectively moving between

1579
01:06:40,460 --> 01:06:38,609
these two galaxies so these systems are

1580
01:06:43,370 --> 01:06:40,470
unstable and we wish we could trace

1581
01:06:44,810 --> 01:06:43,380
things back that far but okay we've got

1582
01:06:45,980 --> 01:06:44,820
a couple kids up in the corner I told

1583
01:06:47,300 --> 01:06:45,990
them they can have a question if they

1584
01:06:49,359 --> 01:06:47,310
have to have it do you have any

1585
01:06:54,259 --> 01:06:49,369
questions for us tonight

1586
01:06:56,450 --> 01:06:54,269
all right I always like you know when we

1587
01:06:58,339 --> 01:06:56,460
get dusk school kids coming I always

1588
01:07:02,569 --> 01:06:58,349

like to answer their questions all right

1589
01:07:05,329 --> 01:07:02,579
next month November 13 the week after

1590
01:07:06,950 --> 01:07:05,339
election day Bill Blair will be talking

1591
01:07:09,140 --> 01:07:06,960
about observing with Hubble the whole

1592
01:07:11,599 --> 01:07:09,150
process from the idea through these

1593
01:07:13,519 --> 01:07:11,609
proposals all the way up to getting your

1594
01:07:15,529 --> 01:07:13,529
data processing it and polishing the

1595
01:07:16,730 --> 01:07:15,539
paper okay observing with Hubble Bill