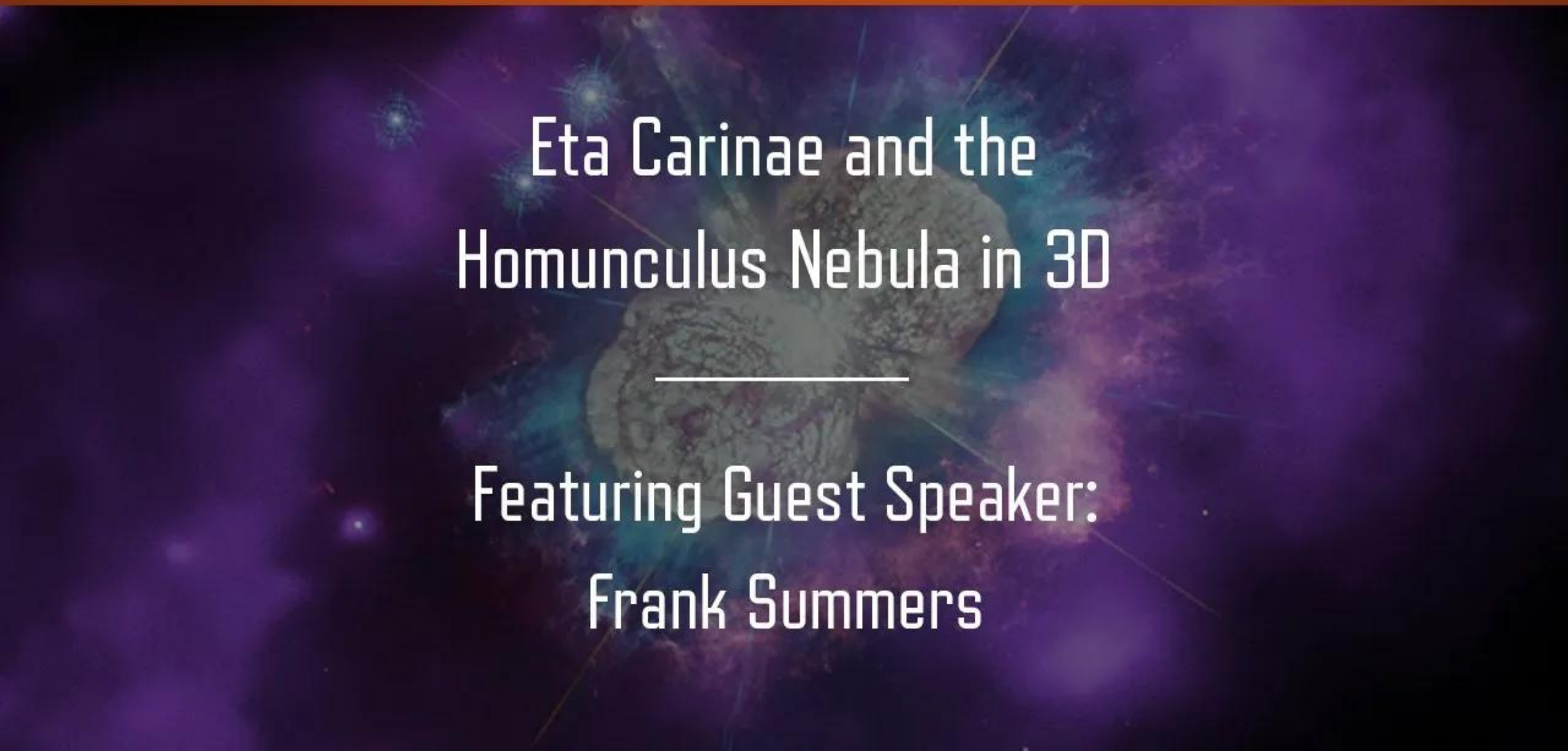
PUBLIC LECTURE SERIES



Eta Carinae and the Homunculus Nebula in 3D

Featuring Guest Speaker: Frank Summers

1
00:00:06,710 --> 00:00:05,269
welcome to the space telescope public

2
00:00:08,150 --> 00:00:06,720
lecture series

3
00:00:11,749 --> 00:00:08,160
tonight's lecture

4
00:00:13,190 --> 00:00:11,759
ada carinae and the homunculus nebula in

5
00:00:15,110 --> 00:00:13,200
3d

6
00:00:16,950 --> 00:00:15,120
by frank summers of the space telescope

7
00:00:18,630 --> 00:00:16,960
science institute

8
00:00:20,870 --> 00:00:18,640
i am your host

9
00:00:23,349 --> 00:00:20,880
also known as frank summers of the space

10
00:00:25,029 --> 00:00:23,359
telescope science institute i work in

11
00:00:27,750 --> 00:00:25,039
the office of public outreach and it is

12
00:00:28,950 --> 00:00:27,760
my pleasure to be your host here each

13
00:00:31,269 --> 00:00:28,960

and every month

14
00:00:34,310 --> 00:00:31,279
it is also my pleasure to thank our

15
00:00:37,190 --> 00:00:34,320
amazing tech team thomas marufu and

16
00:00:40,709 --> 00:00:37,200
grant justice who take care of recording

17
00:00:43,030 --> 00:00:40,719
this and getting it out to youtube

18
00:00:45,430 --> 00:00:43,040
our upcoming talks

19
00:00:46,950 --> 00:00:45,440
on june 7th

20
00:00:50,150 --> 00:00:46,960
understanding the formation and

21
00:00:51,830 --> 00:00:50,160
evolution of galaxies by cameron hummels

22
00:00:54,709 --> 00:00:51,840
of caltech and

23
00:00:55,990 --> 00:00:54,719
cameron is a fantastic guy

24
00:00:58,549 --> 00:00:56,000
i'm really looking forward to seeing

25
00:01:01,670 --> 00:00:58,559
what he has for us next month

26
00:01:03,910 --> 00:01:01,680
in july it is an unscheduled talk

27
00:01:07,109 --> 00:01:03,920
because i was sort of keeping july open

28
00:01:09,350 --> 00:01:07,119
for the uh james webb space telescope uh

29
00:01:11,750 --> 00:01:09,360
but they've pushed to august so now july

30
00:01:14,469 --> 00:01:11,760
is open but i guarantee you we will have

31
00:01:17,350 --> 00:01:14,479
a fascinating topic with an amazing

32
00:01:20,390 --> 00:01:17,360
speaker on july 5th

33
00:01:23,190 --> 00:01:20,400
on august 2nd that's when we will hear

34
00:01:24,310 --> 00:01:23,200
the first results from the web space

35
00:01:25,990 --> 00:01:24,320
telescope

36
00:01:28,070 --> 00:01:26,000
and the web mission office has promised

37
00:01:30,789 --> 00:01:28,080
me a wonderful speaker um they just

38
00:01:33,429 --> 00:01:30,799

haven't said who yet so i know you're

39
00:01:35,030 --> 00:01:33,439
all looking forward to it august 2nd uh

40
00:01:39,429 --> 00:01:35,040
the public lecture series will talk

41
00:01:42,389 --> 00:01:39,439
about the first results from web

42
00:01:46,389 --> 00:01:42,399
to follow this go to our website

43
00:01:51,510 --> 00:01:49,190
public hyphen lectures you will find

44
00:01:54,149 --> 00:01:51,520
this page here

45
00:01:55,990 --> 00:01:54,159
and the links to the webcast on the left

46
00:01:59,030 --> 00:01:56,000
hand side of the page

47
00:02:03,030 --> 00:01:59,040
and the subscribe button for our email

48
00:02:05,830 --> 00:02:03,040
on the right hand side of the page okay

49
00:02:07,670 --> 00:02:05,840
also we will have of course lists of the

50
00:02:09,190 --> 00:02:07,680
upcoming lectures

51
00:02:11,589 --> 00:02:09,200
and if you click on each one of those

52
00:02:14,630 --> 00:02:11,599
lectures all the details of that lecture

53
00:02:16,869 --> 00:02:14,640
appear including the description um and

54
00:02:20,070 --> 00:02:16,879
after it's been recorded links to both

55
00:02:22,710 --> 00:02:20,080
the sdsci webcast and the

56
00:02:25,589 --> 00:02:22,720
recording on youtube

57
00:02:27,670 --> 00:02:25,599
if you would like our announcements um

58
00:02:29,670 --> 00:02:27,680
as i showed you it's very easy just to

59
00:02:32,390 --> 00:02:29,680
enter your email address push the button

60
00:02:34,550 --> 00:02:32,400
and sign up on our website

61
00:02:37,430 --> 00:02:34,560
you could also just subscribe to our

62
00:02:40,390 --> 00:02:37,440
youtube channel this is youtube.com

63
00:02:43,190 --> 00:02:40,400

hubble space telescope all one word

64
00:02:45,350 --> 00:02:43,200
uh you will get notices of new videos

65
00:02:47,830 --> 00:02:45,360
and reminders of live events

66
00:02:49,830 --> 00:02:47,840
like the one you're watching right now

67
00:02:52,150 --> 00:02:49,840
if you finally if you have comments or

68
00:02:57,830 --> 00:02:52,160
questions you can send them to us at

69
00:03:01,990 --> 00:02:59,589
our social media

70
00:03:04,149 --> 00:03:02,000
for the hubble space telescope for the

71
00:03:06,470 --> 00:03:04,159
web space telescope and for the space

72
00:03:09,830 --> 00:03:06,480
telescope science institute is available

73
00:03:11,589 --> 00:03:09,840
on facebook twitter youtube and

74
00:03:14,390 --> 00:03:11,599
instagram

75
00:03:16,630 --> 00:03:14,400
i myself as your host only do a small

76
00:03:18,630 --> 00:03:16,640
amount of social media

77
00:03:22,470 --> 00:03:18,640
and you can find me on facebook and

78
00:03:27,509 --> 00:03:24,550
and now our news from the universe for

79
00:03:29,030 --> 00:03:27,519
may 2022

80
00:03:30,789 --> 00:03:29,040
and as we've done

81
00:03:33,830 --> 00:03:30,799
every month since it launched we're

82
00:03:35,910 --> 00:03:33,840
giving you another web update

83
00:03:38,789 --> 00:03:35,920
alignment check

84
00:03:41,350 --> 00:03:38,799
check all right so the web space

85
00:03:45,110 --> 00:03:41,360
telescope was launched in december

86
00:03:48,309 --> 00:03:45,120
and it reached l2 it uh or orbit orbit

87
00:03:50,470 --> 00:03:48,319
around the l2 point in january

88
00:03:52,470 --> 00:03:50,480

and since that time we've been updating

89
00:03:53,509 --> 00:03:52,480
you on how they've been aligning the

90
00:03:55,350 --> 00:03:53,519
mirrors

91
00:03:58,149 --> 00:03:55,360
and i don't know if quen showed this

92
00:04:00,470 --> 00:03:58,159
last month but uh this was the latest

93
00:04:03,190 --> 00:04:00,480
thing that we had shown before this

94
00:04:05,429 --> 00:04:03,200
month and this is the web near cam

95
00:04:08,309 --> 00:04:05,439
alignment image so

96
00:04:09,990 --> 00:04:08,319
near cam is the near infrared camera

97
00:04:13,670 --> 00:04:10,000
it's kind of going to be the workhorse

98
00:04:15,910 --> 00:04:13,680
camera of of web in producing images

99
00:04:19,749 --> 00:04:15,920
and it was the first to be aligned and

100
00:04:22,710 --> 00:04:19,759
look at this gorgeous pixi star and as

101
00:04:25,030 --> 00:04:22,720
we've discussed it has a six-pointed

102
00:04:27,030 --> 00:04:25,040
star along with you know two extra

103
00:04:30,469 --> 00:04:27,040
little point uh struts that come out the

104
00:04:31,909 --> 00:04:30,479
center so this is the psf the point

105
00:04:34,550 --> 00:04:31,919
spread function

106
00:04:38,070 --> 00:04:34,560
for the web space telescope um and it's

107
00:04:39,030 --> 00:04:38,080
just like absolutely clean and gorgeous

108
00:04:42,230 --> 00:04:39,040
but

109
00:04:43,430 --> 00:04:42,240
near cam is only one of the instruments

110
00:04:45,909 --> 00:04:43,440
on web

111
00:04:48,469 --> 00:04:45,919
and here is the focal plane and all of

112
00:04:50,469 --> 00:04:48,479
the instruments out there so near cam is

113
00:04:53,270 --> 00:04:50,479

here in the center

114
00:04:55,350 --> 00:04:53,280
on the up left is near spec the near and

115
00:04:58,469 --> 00:04:55,360
infrared spectrometer

116
00:04:59,990 --> 00:04:58,479
down here is the fgs the fine guidance

117
00:05:01,350 --> 00:05:00,000
sensor

118
00:05:04,230 --> 00:05:01,360
this one is

119
00:05:09,830 --> 00:05:07,270
in here infrared imager

120
00:05:12,070 --> 00:05:09,840
and slitless spectroscopy

121
00:05:15,189 --> 00:05:12,080
and in the upper right we have miri the

122
00:05:18,070 --> 00:05:15,199
near the mid infrared instrument so

123
00:05:20,390 --> 00:05:18,080
there are five major instruments on web

124
00:05:23,590 --> 00:05:20,400
and all of them can be used for science

125
00:05:26,310 --> 00:05:23,600
so after aligning uh near cam they went

126
00:05:28,310 --> 00:05:26,320
on to align all of the other instruments

127
00:05:30,390 --> 00:05:28,320
and they took observations of the same

128
00:05:31,430 --> 00:05:30,400
field at different times of course

129
00:05:33,749 --> 00:05:31,440
because they were using different

130
00:05:36,469 --> 00:05:33,759
different uh that they sent a light to

131
00:05:38,790 --> 00:05:36,479
different instruments and they checked

132
00:05:41,189 --> 00:05:38,800
it out and so here is the

133
00:05:42,870 --> 00:05:41,199
what they call the web telescope image

134
00:05:46,150 --> 00:05:42,880
sharpness check

135
00:05:49,590 --> 00:05:46,160
and look at this this is all five

136
00:05:51,830 --> 00:05:49,600
instruments beautifully aligned okay um

137
00:05:53,510 --> 00:05:51,840
and you can't really tell from here so

138
00:05:56,070 --> 00:05:53,520

they added another version of this with

139
00:05:58,469 --> 00:05:56,080
some details all right and there you can

140
00:06:01,830 --> 00:05:58,479
see those beautiful six-pointed stars

141
00:06:03,990 --> 00:06:01,840
over in nearest and in the fgs and in

142
00:06:06,469 --> 00:06:04,000
near spec as well as what was we saw

143
00:06:09,830 --> 00:06:06,479
from near cam last month and all the way

144
00:06:12,629 --> 00:06:09,840
up there on right in miri as well

145
00:06:15,510 --> 00:06:12,639
so this is really cool and one of the

146
00:06:17,270 --> 00:06:15,520
things that reminds me is that for a lot

147
00:06:18,790 --> 00:06:17,280
of the near infrared

148
00:06:21,990 --> 00:06:18,800
a good amount of what you're going to

149
00:06:24,230 --> 00:06:22,000
see is stars because um

150
00:06:27,510 --> 00:06:24,240
the the gas in the infrared doesn't show

151
00:06:29,749 --> 00:06:27,520
up until about four microns um and miri

152
00:06:32,550 --> 00:06:29,759
starts at five microns so mirrors we're

153
00:06:35,510 --> 00:06:32,560
going to get the most of the gas

154
00:06:37,590 --> 00:06:35,520
near cam nearest and such will have some

155
00:06:40,309 --> 00:06:37,600
some gas in it but it's going to be an

156
00:06:43,510 --> 00:06:40,319
awful lot of stars a whole lot of really

157
00:06:47,029 --> 00:06:43,520
beautiful gorgeous six-pointed stars

158
00:06:48,309 --> 00:06:47,039
and so the natural question we have

159
00:06:50,950 --> 00:06:48,319
when you look at something like this is

160
00:06:53,270 --> 00:06:50,960
okay this is really great but but how

161
00:06:56,390 --> 00:06:53,280
does this actually compare

162
00:06:58,070 --> 00:06:56,400
to previous space telescopes and

163
00:07:01,430 --> 00:06:58,080

of course we weren't the only ones who

164
00:07:07,430 --> 00:07:04,309
gas bar actually went out and found

165
00:07:09,189 --> 00:07:07,440
observations of that same field with

166
00:07:12,710 --> 00:07:09,199
previous telescopes

167
00:07:14,950 --> 00:07:12,720
so what you see on the left is the wise

168
00:07:18,790 --> 00:07:14,960
space telescope

169
00:07:22,150 --> 00:07:18,800
at 4.6 microns then you have the spitzer

170
00:07:23,270 --> 00:07:22,160
space telescope at 8.6 microns spitzer

171
00:07:25,430 --> 00:07:23,280
was the

172
00:07:27,589 --> 00:07:25,440
great observatory that was retired a

173
00:07:29,430 --> 00:07:27,599
year and a half

174
00:07:31,430 --> 00:07:29,440
a little over a year ago

175
00:07:34,950 --> 00:07:31,440
and then you have the observation from

176
00:07:37,430 --> 00:07:34,960
miri at 7.7 microns so these are roughly

177
00:07:40,870 --> 00:07:37,440
comparing apples to apples here

178
00:07:43,749 --> 00:07:40,880
and you see just how much more detail

179
00:07:46,070 --> 00:07:43,759
miri has than spitzer and so much more

180
00:07:49,589 --> 00:07:46,080
than wise itself so

181
00:07:51,909 --> 00:07:49,599
yes this is a quantum leap in infrared

182
00:07:54,790 --> 00:07:51,919
astronomy uh being done with the

183
00:07:56,390 --> 00:07:54,800
webspace telescope and we're all just

184
00:07:57,510 --> 00:07:56,400
chomping on the bit for those first

185
00:07:59,430 --> 00:07:57,520
images

186
00:08:01,510 --> 00:07:59,440
how long is that going to take

187
00:08:03,589 --> 00:08:01,520
well here is the chart i showed you

188
00:08:04,790 --> 00:08:03,599

several months ago about webb's

189
00:08:07,189 --> 00:08:04,800
commissioning

190
00:08:10,070 --> 00:08:07,199
we arrived at l2 about 30 days after

191
00:08:11,749 --> 00:08:10,080
launch and this green stuff here all

192
00:08:12,390 --> 00:08:11,759
right all of this green stuff around

193
00:08:15,350 --> 00:08:12,400
here

194
00:08:17,589 --> 00:08:15,360
is the instrument focusing and alignment

195
00:08:19,189 --> 00:08:17,599
so we have now gotten to the end of the

196
00:08:21,589 --> 00:08:19,199
green stuff okay

197
00:08:23,189 --> 00:08:21,599
um and there are only a couple more

198
00:08:25,270 --> 00:08:23,199
months and this is the science

199
00:08:27,430 --> 00:08:25,280
instrument commissioning phase we have

200
00:08:29,670 --> 00:08:27,440
moved out of the

201
00:08:32,149 --> 00:08:29,680
um alignment and getting getting things

202
00:08:33,990 --> 00:08:32,159
set and now we start the science

203
00:08:35,909 --> 00:08:34,000
instrument commissioning phase and

204
00:08:37,110 --> 00:08:35,919
that's really exciting because you know

205
00:08:37,909 --> 00:08:37,120
we are

206
00:08:40,949 --> 00:08:37,919
two

207
00:08:43,589 --> 00:08:40,959
three months at most away from seeing

208
00:08:46,470 --> 00:08:43,599
these amazing images from

209
00:08:47,829 --> 00:08:46,480
the web space telescope

210
00:08:50,790 --> 00:08:47,839
that's all i have for the news from

211
00:08:52,550 --> 00:08:50,800
universe it's time to move on to our

212
00:08:55,829 --> 00:08:52,560
featured talk

213
00:08:58,630 --> 00:08:55,839

and our speaker tonight is me

214
00:09:04,790 --> 00:09:01,829
uh uh many of you know me uh because

215
00:09:07,030 --> 00:09:04,800
i've been doing this for almost 20 years

216
00:09:10,949 --> 00:09:07,040
now um

217
00:09:12,949 --> 00:09:10,959
let's see it will be 20 years in june in

218
00:09:15,750 --> 00:09:12,959
june of this year it'll be 20 years that

219
00:09:18,310 --> 00:09:15,760
i have been hosting the public lecture

220
00:09:20,550 --> 00:09:18,320
series so a lot of you know my resume

221
00:09:22,790 --> 00:09:20,560
some of you don't and so let me just

222
00:09:25,190 --> 00:09:22,800
give you the basics

223
00:09:28,310 --> 00:09:25,200
i did my undergraduate degree at

224
00:09:29,910 --> 00:09:28,320
virginia tech and my graduate degree

225
00:09:32,470 --> 00:09:29,920
in astronomy at the university of

226
00:09:36,070 --> 00:09:32,480
california berkeley

227
00:09:37,990 --> 00:09:36,080
i then went on and did post-docs at the

228
00:09:39,540 --> 00:09:38,000
princeton university and columbia

229
00:09:40,790 --> 00:09:39,550
university

230
00:09:43,670 --> 00:09:40,800
[Music]

231
00:09:45,750 --> 00:09:43,680
before switching from research oriented

232
00:09:48,150 --> 00:09:45,760
to outreach oriented

233
00:09:50,389 --> 00:09:48,160
you see because neil tyson was in the

234
00:09:53,110 --> 00:09:50,399
office next to me at princeton

235
00:09:55,910 --> 00:09:53,120
and he hired me to start working on the

236
00:09:58,230 --> 00:09:55,920
rebuilding of the hayden planetary

237
00:09:59,750 --> 00:09:58,240
that turned into the

238
00:10:02,389 --> 00:09:59,760

complete demolition of the hidden

239
00:10:04,470 --> 00:10:02,399
planetarium and rebuilding it up as the

240
00:10:06,630 --> 00:10:04,480
rose center for earth in space and that

241
00:10:08,150 --> 00:10:06,640
took about five years that i was in new

242
00:10:12,389 --> 00:10:08,160
york city

243
00:10:14,389 --> 00:10:12,399
down to baltimore

244
00:10:17,190 --> 00:10:14,399
where i've been working on the hubble

245
00:10:19,750 --> 00:10:17,200
project ever since

246
00:10:21,590 --> 00:10:19,760
i always like to share one

247
00:10:23,509 --> 00:10:21,600
interesting tidbit about myself and i

248
00:10:25,590 --> 00:10:23,519
can't really remember what interesting

249
00:10:26,310 --> 00:10:25,600
tidbits i've shared previously

250
00:10:27,190 --> 00:10:26,320
so

251
00:10:29,350 --> 00:10:27,200
uh

252
00:10:30,870 --> 00:10:29,360
today i'll tell i'll just tell you that

253
00:10:33,190 --> 00:10:30,880
i met my wife

254
00:10:35,430 --> 00:10:33,200
at the ballroom dance club at the

255
00:10:37,829 --> 00:10:35,440
university of california berkeley

256
00:10:40,310 --> 00:10:37,839
go bears

257
00:10:42,630 --> 00:10:40,320
turns out there was a good number of

258
00:10:44,470 --> 00:10:42,640
physicists and astronomers and other

259
00:10:45,590 --> 00:10:44,480
technical types who took ballroom

260
00:10:49,750 --> 00:10:45,600
dancing

261
00:10:53,269 --> 00:10:49,760
social club i know of at least three

262
00:10:54,710 --> 00:10:53,279
marriages that came out of the um uh out

263
00:10:57,190 --> 00:10:54,720

of the university of california ballroom

264
00:10:59,509 --> 00:10:57,200
dance club mine fortunately was one of

265
00:11:03,190 --> 00:10:59,519
them all right so ladies and gentlemen

266
00:11:08,230 --> 00:11:04,949
all right now that i've introduced

267
00:11:10,069 --> 00:11:08,240
myself let's start my my talk um i'm

268
00:11:11,590 --> 00:11:10,079
going to talk to you tonight about

269
00:11:15,350 --> 00:11:11,600
edicarinae

270
00:11:18,550 --> 00:11:15,360
and the homunculus nebula in 3d

271
00:11:21,670 --> 00:11:18,560
and i am not an expert in edocarinate

272
00:11:24,069 --> 00:11:21,680
okay um i'm a strong visualizer i call

273
00:11:26,790 --> 00:11:24,079
myself an astrophysicist

274
00:11:29,350 --> 00:11:26,800
but in order to do any visualization i

275
00:11:31,590 --> 00:11:29,360
need to do a lot of homework read a lot

276
00:11:33,350 --> 00:11:31,600
of scientific papers and study other

277
00:11:35,110 --> 00:11:33,360
people's research and i'm going to give

278
00:11:38,069 --> 00:11:35,120
you some of the feel of that

279
00:11:39,829 --> 00:11:38,079
as we tell the story of adacar

280
00:11:42,069 --> 00:11:39,839
and we're going to start

281
00:11:43,430 --> 00:11:42,079
by talking about the brightest star in

282
00:11:46,150 --> 00:11:43,440
the night sky

283
00:11:47,430 --> 00:11:46,160
and as many of you know it is as shown

284
00:11:50,310 --> 00:11:47,440
here sirius which is in the

285
00:11:52,949 --> 00:11:50,320
constellation of canis major

286
00:11:56,230 --> 00:11:52,959
that is right next to the constellation

287
00:11:59,110 --> 00:11:56,240
of orion because canis major is one of

288
00:12:02,550 --> 00:11:59,120

the hunting dogs of orion and orion has

289
00:12:04,389 --> 00:12:02,560
its famous stars of betelgeuse and rigel

290
00:12:07,030 --> 00:12:04,399
and it also has the

291
00:12:09,590 --> 00:12:07,040
small dog canis minor

292
00:12:11,750 --> 00:12:09,600
and its bright star procyon

293
00:12:13,990 --> 00:12:11,760
so sirius the brightest star in the

294
00:12:16,150 --> 00:12:14,000
night sky is in a very interesting

295
00:12:18,470 --> 00:12:16,160
region of the sky

296
00:12:20,870 --> 00:12:18,480
but there's also a very interesting

297
00:12:22,230 --> 00:12:20,880
region around the second brightest star

298
00:12:24,550 --> 00:12:22,240
in the night sky

299
00:12:27,190 --> 00:12:24,560
have you ever thought what that one is

300
00:12:30,470 --> 00:12:27,200
most people don't really know it um but

301
00:12:32,710 --> 00:12:30,480
i will tell you it is the star canopus

302
00:12:33,829 --> 00:12:32,720
and this is a wonderful image from kira

303
00:12:36,870 --> 00:12:33,839
fujii

304
00:12:39,110 --> 00:12:36,880
having both sirius and canopa canopus

305
00:12:40,790 --> 00:12:39,120
and a huge swath of the sky i love these

306
00:12:43,190 --> 00:12:40,800
wide field images

307
00:12:46,790 --> 00:12:43,200
canopus is part of the ancient

308
00:12:48,870 --> 00:12:46,800
constellation called argo novice all

309
00:12:50,069 --> 00:12:48,880
right now you may not have heard of that

310
00:12:52,949 --> 00:12:50,079
because

311
00:12:54,870 --> 00:12:52,959
we no longer recognize it okay it was a

312
00:12:57,110 --> 00:12:54,880
constellation that people thought about

313
00:12:58,629 --> 00:12:57,120

in the old days it's this giant ship

314
00:12:59,910 --> 00:12:58,639
it's the actually the ship of the

315
00:13:02,310 --> 00:12:59,920
argonauts

316
00:13:04,069 --> 00:13:02,320
um and you can see it covers a huge

317
00:13:06,550 --> 00:13:04,079
swath of the sky

318
00:13:09,430 --> 00:13:06,560
so astronomers decided to change things

319
00:13:12,629 --> 00:13:09,440
around and break up argo novice into

320
00:13:15,430 --> 00:13:12,639
three separate constellations uh that is

321
00:13:16,550 --> 00:13:15,440
shown here as karina the keel of the

322
00:13:22,069 --> 00:13:16,560
ship

323
00:13:24,550 --> 00:13:22,079
the poop deck

324
00:13:27,190 --> 00:13:24,560
so if you're like me and you live in the

325
00:13:29,030 --> 00:13:27,200
northern hemisphere well you probably

326
00:13:31,350 --> 00:13:29,040
haven't seen these constellations a

327
00:13:32,790 --> 00:13:31,360
matter of fact i only got to see this

328
00:13:35,350 --> 00:13:32,800
region of the sky

329
00:13:38,150 --> 00:13:35,360
once in my life when i was invited down

330
00:13:40,230 --> 00:13:38,160
to brazil to give a talk

331
00:13:42,870 --> 00:13:40,240
and also in that talk

332
00:13:43,990 --> 00:13:42,880
also on the program of that conference

333
00:13:47,590 --> 00:13:44,000
was the

334
00:13:48,550 --> 00:13:47,600
wonderful astrophotographer tunschtessel

335
00:13:52,870 --> 00:13:48,560
from

336
00:13:54,790 --> 00:13:52,880
and he invited me to go out

337
00:13:56,870 --> 00:13:54,800
and do some astrophotography with him

338
00:13:59,189 --> 00:13:56,880

one night during the conference

339
00:14:01,189 --> 00:13:59,199
and on the right you can see an amazing

340
00:14:03,590 --> 00:14:01,199
image where you've got the galactic

341
00:14:05,990 --> 00:14:03,600
center and this wonderful stretch of

342
00:14:08,629 --> 00:14:06,000
really interesting sky really nice and

343
00:14:10,069 --> 00:14:08,639
high and we don't get that in the um in

344
00:14:11,350 --> 00:14:10,079
the northern hemisphere you only get

345
00:14:14,230 --> 00:14:11,360
that from the southern hemisphere where

346
00:14:15,430 --> 00:14:14,240
you really get the milky way up nice and

347
00:14:17,910 --> 00:14:15,440
high

348
00:14:20,949 --> 00:14:17,920
and i have proof that i was there

349
00:14:22,230 --> 00:14:20,959
because if you look right here

350
00:14:23,590 --> 00:14:22,240
that's me

351
00:14:26,389 --> 00:14:23,600
um

352
00:14:29,829 --> 00:14:26,399
uh did a wonderful thing where he took a

353
00:14:32,310 --> 00:14:29,839
a portrait of me with the galactus guy

354
00:14:35,030 --> 00:14:32,320
and that is something that i treasure uh

355
00:14:36,790 --> 00:14:35,040
because of it is just such an amazing

356
00:14:38,949 --> 00:14:36,800
experience to be out with him

357
00:14:41,509 --> 00:14:38,959
but let's take a look at the

358
00:14:43,590 --> 00:14:41,519
at this region uh we have canopus here

359
00:14:46,550 --> 00:14:43,600
on the right and all the way over on the

360
00:14:49,829 --> 00:14:46,560
left we have alpha centauri which is the

361
00:14:52,150 --> 00:14:49,839
nearest bright star to the sun

362
00:14:54,629 --> 00:14:52,160
uh alpha centauri is the same spectral

363
00:14:56,949 --> 00:14:54,639

type as as the sun and it's only like

364
00:14:58,790 --> 00:14:56,959
four and a third light years away

365
00:15:00,949 --> 00:14:58,800
there's actually one star that's even

366
00:15:03,509 --> 00:15:00,959
closer proxima centauri but that's a

367
00:15:06,790 --> 00:15:03,519
really faint little red star so alpha

368
00:15:07,990 --> 00:15:06,800
centauri is the one you can look at

369
00:15:10,230 --> 00:15:08,000
if you come

370
00:15:11,269 --> 00:15:10,240
next to alpha centauri is the southern

371
00:15:13,829 --> 00:15:11,279
cross

372
00:15:15,829 --> 00:15:13,839
the constellation called crux

373
00:15:17,590 --> 00:15:15,839
and across from that

374
00:15:18,710 --> 00:15:17,600
is something that we call the false

375
00:15:26,629 --> 00:15:18,720
cross

376
00:15:28,790 --> 00:15:26,639
pattern and actually when i was there

377
00:15:29,990 --> 00:15:28,800
looking at it i got up the two confused

378
00:15:32,230 --> 00:15:30,000
and it took me a while to really

379
00:15:34,069 --> 00:15:32,240
recognize okay there's the cross and

380
00:15:36,790 --> 00:15:34,079
there's the false cross

381
00:15:39,990 --> 00:15:36,800
and right in between these two is our

382
00:15:41,670 --> 00:15:40,000
destination and that is the karina

383
00:15:45,110 --> 00:15:41,680
nebula okay

384
00:15:46,870 --> 00:15:45,120
so the karina nebula is an amazing place

385
00:15:49,350 --> 00:15:46,880
um and i'm going to back off just a

386
00:15:52,150 --> 00:15:49,360
little bit uh to tell you to show you

387
00:15:52,870 --> 00:15:52,160
where it's located in the galaxy

388
00:15:56,150 --> 00:15:52,880

so

389
00:15:58,230 --> 00:15:56,160
on a all sky of the galaxy

390
00:15:59,590 --> 00:15:58,240
uh you can see that the galactic center

391
00:16:02,629 --> 00:15:59,600
is in here

392
00:16:04,629 --> 00:16:02,639
and the carina nebula is over here all

393
00:16:07,670 --> 00:16:04,639
right so it's in the direction of the

394
00:16:09,509 --> 00:16:07,680
galactic center but it's not against all

395
00:16:11,990 --> 00:16:09,519
that light of the galactic center and

396
00:16:15,749 --> 00:16:12,000
the bulge so it's far enough away that

397
00:16:18,310 --> 00:16:15,759
we can we can look at it indeed indeed

398
00:16:20,150 --> 00:16:18,320
without too much background confusion

399
00:16:22,629 --> 00:16:20,160
and if you look at the plan view of the

400
00:16:25,269 --> 00:16:22,639
galaxy looking down onto it this is a

401
00:16:27,189 --> 00:16:25,279
drawing by robert hurt

402
00:16:28,710 --> 00:16:27,199
this drawing is oriented such that the

403
00:16:30,870 --> 00:16:28,720
sun is here

404
00:16:33,430 --> 00:16:30,880
and let's zoom in on that

405
00:16:37,430 --> 00:16:33,440
and with the sun here the carina nebula

406
00:16:40,790 --> 00:16:37,440
is over here in the next spiral arm over

407
00:16:44,389 --> 00:16:40,800
this is the sagittarius spiral arm

408
00:16:46,949 --> 00:16:44,399
so the karina nebula is only about 7 500

409
00:16:49,189 --> 00:16:46,959
light years away which you know sounds

410
00:16:50,629 --> 00:16:49,199
big but it's actually really close when

411
00:16:53,590 --> 00:16:50,639
you're talking about these giant

412
00:16:56,550 --> 00:16:53,600
star-forming regions so it's a really

413
00:16:58,870 --> 00:16:56,560

good view of the carina nebula from our

414
00:17:02,949 --> 00:17:00,389
this is the creator nebula from the

415
00:17:04,789 --> 00:17:02,959
digitized sky survey

416
00:17:08,150 --> 00:17:04,799
it contains a

417
00:17:11,669 --> 00:17:08,160
thousands of thousands of stars and one

418
00:17:14,309 --> 00:17:11,679
um researcher described it as the

419
00:17:17,110 --> 00:17:14,319
most amazing place for studying high

420
00:17:19,429 --> 00:17:17,120
mass stars that there are more high mass

421
00:17:22,390 --> 00:17:19,439
stars of interest that you can study in

422
00:17:25,429 --> 00:17:22,400
in detail than any other place

423
00:17:28,309 --> 00:17:25,439
we zoom in a little bit closer uh this

424
00:17:29,510 --> 00:17:28,319
is a really really high resolution image

425
00:17:32,230 --> 00:17:29,520
from the

426
00:17:34,070 --> 00:17:32,240
very large telescope the vlt

427
00:17:36,150 --> 00:17:34,080
uh and you can see that it alternates

428
00:17:39,510 --> 00:17:36,160
between these bright areas where you've

429
00:17:42,390 --> 00:17:39,520
got newly formed stars or stars that are

430
00:17:44,310 --> 00:17:42,400
pointing and these dark lanes of dust

431
00:17:45,990 --> 00:17:44,320
that are on the foreground sort of

432
00:17:48,070 --> 00:17:46,000
blocking our views so there's a lot of

433
00:17:49,990 --> 00:17:48,080
star formation there's dust that's

434
00:17:52,630 --> 00:17:50,000
collapsing and there's a lot of uh

435
00:17:56,230 --> 00:17:52,640
interesting things going on here

436
00:17:58,870 --> 00:17:56,240
hubble has a very famous

437
00:18:01,190 --> 00:17:58,880
montage a mosaic image one of the

438
00:18:02,390 --> 00:18:01,200

largest mosaics hubble's ever done in

439
00:18:04,789 --> 00:18:02,400
this region

440
00:18:07,190 --> 00:18:04,799
and we zoom into that

441
00:18:09,669 --> 00:18:07,200
and you can see there's just a ton of

442
00:18:11,830 --> 00:18:09,679
things happening here the stars and the

443
00:18:13,830 --> 00:18:11,840
gas and the dust and matter of fact

444
00:18:17,029 --> 00:18:13,840
there are at least

445
00:18:19,430 --> 00:18:17,039
three hubble press release images that

446
00:18:21,669 --> 00:18:19,440
have come from this region so this one

447
00:18:24,070 --> 00:18:21,679
big image was it was released but also

448
00:18:28,310 --> 00:18:24,080
these here and the dark pillars down

449
00:18:29,990 --> 00:18:28,320
here the light and shadow image up here

450
00:18:32,310 --> 00:18:30,000
and one of my favorites the mystic

451
00:18:34,150 --> 00:18:32,320
mountain image over here

452
00:18:35,510 --> 00:18:34,160
really cool stuff

453
00:18:37,909 --> 00:18:35,520
all right but

454
00:18:40,549 --> 00:18:37,919
what i want to talk about

455
00:18:42,630 --> 00:18:40,559
shows up really good in an optical but

456
00:18:45,669 --> 00:18:42,640
shows up even better

457
00:18:47,669 --> 00:18:45,679
when we go to the infrared

458
00:18:48,789 --> 00:18:47,679
this is the infrared view of the carina

459
00:18:51,029 --> 00:18:48,799
nebula

460
00:18:54,070 --> 00:18:51,039
from the spitzer space telescope

461
00:18:55,590 --> 00:18:54,080
and when i remove that hubble overlay

462
00:18:56,549 --> 00:18:55,600
you can see

463
00:19:12,789 --> 00:18:56,559

a

464
00:19:14,870 --> 00:19:12,799
object on the night sky

465
00:19:16,870 --> 00:19:14,880
in infrared wavelengths

466
00:19:18,870 --> 00:19:16,880
right so you know if you think about you

467
00:19:20,789 --> 00:19:18,880
know sirius being the brightest star in

468
00:19:24,630 --> 00:19:20,799
the night sky invisible

469
00:19:26,789 --> 00:19:24,640
ada car is the brightest in infrared

470
00:19:29,510 --> 00:19:26,799
and we zoom in a little bit and you can

471
00:19:32,549 --> 00:19:29,520
see the effect that adacar has had on

472
00:19:35,110 --> 00:19:32,559
the gas and dust in the carina nebula

473
00:19:37,750 --> 00:19:35,120
you can see that it's evacuated this big

474
00:19:40,470 --> 00:19:37,760
cavity around it with its strong

475
00:19:43,750 --> 00:19:40,480
radiation and strong stellar winds

476
00:19:46,230 --> 00:19:43,760
you can also see these pillars down here

477
00:19:49,430 --> 00:19:46,240
that are all pointing toward it which

478
00:19:52,070 --> 00:19:49,440
shows that the wind from adacar

479
00:19:54,549 --> 00:19:52,080
blowing out across the nebula creating

480
00:19:55,990 --> 00:19:54,559
these pillars that point back toward the

481
00:19:59,270 --> 00:19:56,000
source

482
00:20:00,950 --> 00:19:59,280
so adacar is really something special in

483
00:20:02,950 --> 00:20:00,960
infrared

484
00:20:04,549 --> 00:20:02,960
however that's not what it's actually

485
00:20:07,190 --> 00:20:04,559
particularly known for

486
00:20:09,510 --> 00:20:07,200
it's actually known for something called

487
00:20:11,750 --> 00:20:09,520
the great eruption

488
00:20:12,870 --> 00:20:11,760

and that occurred invisible

489
00:20:16,630 --> 00:20:12,880
so

490
00:20:19,430 --> 00:20:16,640
this is the light curve of eta car from

491
00:20:23,190 --> 00:20:19,440
1800 to today

492
00:20:24,789 --> 00:20:23,200
and you can see around 1840s 1835 to

493
00:20:27,830 --> 00:20:24,799
1855

494
00:20:30,789 --> 00:20:27,840
there was a jump in its light

495
00:20:33,270 --> 00:20:30,799
this is what's called the great eruption

496
00:20:34,470 --> 00:20:33,280
all right and it brightened

497
00:20:37,350 --> 00:20:34,480
and it became

498
00:20:39,750 --> 00:20:37,360
temporarily brighter than canopus

499
00:20:41,750 --> 00:20:39,760
so for a very short time it was the

500
00:20:43,669 --> 00:20:41,760
second brightest star in the night sky

501
00:20:46,630 --> 00:20:43,679
in visible light

502
00:20:49,510 --> 00:20:46,640
but then over the next ensuing decades

503
00:20:53,350 --> 00:20:49,520
it slowly faded away

504
00:20:54,390 --> 00:20:53,360
all right until the late 1800s

505
00:20:56,470 --> 00:20:54,400
then

506
00:20:57,669 --> 00:20:56,480
it underwent a

507
00:20:58,789 --> 00:20:57,679
small

508
00:21:00,950 --> 00:20:58,799
brightening

509
00:21:03,430 --> 00:21:00,960
and decrease which some which

510
00:21:06,549 --> 00:21:03,440
researchers have have taken to calling

511
00:21:09,430 --> 00:21:06,559
the lesser eruption

512
00:21:14,390 --> 00:21:09,440
so in the 1890s ada carr had another

513
00:21:17,190 --> 00:21:14,400

eruption but then again it faded away

514
00:21:20,870 --> 00:21:17,200
it stayed down for a few decades but in

515
00:21:21,990 --> 00:21:20,880
around the 1930s 1940s it had a fast

516
00:21:27,510 --> 00:21:22,000
rise

517
00:21:29,750 --> 00:21:27,520
the 20th century so this is really

518
00:21:32,310 --> 00:21:29,760
really unusual especially when you

519
00:21:35,190 --> 00:21:32,320
consider the difference between getting

520
00:21:37,110 --> 00:21:35,200
up to you know minus one magnitude and

521
00:21:39,110 --> 00:21:37,120
all the way down to you know eight or

522
00:21:41,350 --> 00:21:39,120
eight or ninth magnitude

523
00:21:44,390 --> 00:21:41,360
and five orders of magnitude is a factor

524
00:21:47,110 --> 00:21:44,400
of a hundred in brightness okay

525
00:21:48,390 --> 00:21:47,120
so this is almost a factor of 10 000 in

526
00:21:50,630 --> 00:21:48,400
brightness certainly

527
00:21:53,669 --> 00:21:50,640
about at least a factor of 3 000 and

528
00:21:55,750 --> 00:21:53,679
brightness between its peak um and its

529
00:21:56,870 --> 00:21:55,760
trough down here

530
00:21:59,430 --> 00:21:56,880
so

531
00:22:03,590 --> 00:21:59,440
this is one of the things that makes it

532
00:22:06,149 --> 00:22:03,600
being called a supernova imposter

533
00:22:07,830 --> 00:22:06,159
because of this massive brightening

534
00:22:09,750 --> 00:22:07,840
now just to make sure you remember what

535
00:22:12,390 --> 00:22:09,760
a supernova is

536
00:22:15,029 --> 00:22:12,400
this is uh images from david malin of

537
00:22:18,149 --> 00:22:15,039
supernova 1987a

538
00:22:21,029 --> 00:22:18,159

and on the left is the before image

539
00:22:24,230 --> 00:22:21,039
and on the right is the after image the

540
00:22:25,430 --> 00:22:24,240
supernova is an incredible brightening

541
00:22:27,909 --> 00:22:25,440
however

542
00:22:30,950 --> 00:22:27,919
the star that went supernova here to

543
00:22:33,990 --> 00:22:30,960
make 87a no longer exists because it

544
00:22:36,950 --> 00:22:34,000
exploded it blew itself up its guts are

545
00:22:38,710 --> 00:22:36,960
streaming across interstellar space

546
00:22:41,430 --> 00:22:38,720
right now

547
00:22:44,630 --> 00:22:41,440
ate carr on the other hand

548
00:22:47,110 --> 00:22:44,640
did not go away it survived this massive

549
00:22:50,470 --> 00:22:47,120
brightening this eruption

550
00:22:53,029 --> 00:22:50,480
um and still come as is coming back um

551
00:22:54,390 --> 00:22:53,039
and it was rising and may even get back

552
00:22:55,270 --> 00:22:54,400
up to its uh

553
00:23:00,230 --> 00:22:55,280
uh

554
00:23:02,950 --> 00:23:00,240
so because it had a supernova-like

555
00:23:05,029 --> 00:23:02,960
brightening but it survived that's hence

556
00:23:06,230 --> 00:23:05,039
it comes with the name a supernova

557
00:23:07,909 --> 00:23:06,240
imposter

558
00:23:10,870 --> 00:23:07,919
so that's what adacar is really known

559
00:23:13,350 --> 00:23:10,880
for and when we look at it today what do

560
00:23:17,350 --> 00:23:13,360
we see

561
00:23:20,230 --> 00:23:17,360
the homunculus nebula

562
00:23:23,190 --> 00:23:20,240
yeah this is really cool all right the

563
00:23:24,310 --> 00:23:23,200

star is down deep in here but it's

564
00:23:26,549 --> 00:23:24,320
actually

565
00:23:28,549 --> 00:23:26,559
behind the is buried inside the

566
00:23:30,070 --> 00:23:28,559
homunculus nebula and we can't really

567
00:23:31,750 --> 00:23:30,080
see the star we can see some of the

568
00:23:33,430 --> 00:23:31,760
light from the star but we don't see the

569
00:23:37,750 --> 00:23:33,440
star itself

570
00:23:40,310 --> 00:23:37,760
all right the homunculus nebula is a

571
00:23:43,990 --> 00:23:40,320
cloud of gas and dust that is blocking

572
00:23:46,070 --> 00:23:44,000
the light of the uh of ada car

573
00:23:48,549 --> 00:23:46,080
and you can see that its shape is here

574
00:23:50,950 --> 00:23:48,559
is that it's got bipolar lobes is what

575
00:23:53,269 --> 00:23:50,960
we describe it in thing basically think

576
00:23:55,350 --> 00:23:53,279
of it as an hourglass there's a bubble

577
00:23:56,789 --> 00:23:55,360
coming toward us there's a bubble going

578
00:23:59,909 --> 00:23:56,799
away from us

579
00:24:02,630 --> 00:23:59,919
it also has what i call equatorial

580
00:24:04,390 --> 00:24:02,640
emission so stuff at the

581
00:24:07,029 --> 00:24:04,400
at the center of it there's stuff

582
00:24:08,070 --> 00:24:07,039
spewing out on the equator equatorial

583
00:24:09,430 --> 00:24:08,080
plane

584
00:24:11,430 --> 00:24:09,440
um

585
00:24:14,710 --> 00:24:11,440
and so this is really kind of

586
00:24:17,510 --> 00:24:14,720
interesting that there's this nebula

587
00:24:19,110 --> 00:24:17,520
and hubble has observed this nebula over

588
00:24:22,470 --> 00:24:19,120

its lifetime

589
00:24:24,789 --> 00:24:22,480
and we'll start with the 1995 image

590
00:24:26,230 --> 00:24:24,799
and then watch the nebula because it's

591
00:24:29,430 --> 00:24:26,240
going to grow

592
00:24:32,710 --> 00:24:29,440
here it is in 2008

593
00:24:35,190 --> 00:24:32,720
and here it is in 2018

594
00:24:36,789 --> 00:24:35,200
yeah we're watching it grow and you

595
00:24:38,630 --> 00:24:36,799
might say oh well you're just aligning

596
00:24:41,750 --> 00:24:38,640
the no no take a look at these

597
00:24:44,470 --> 00:24:41,760
stars here okay i'll go back

598
00:24:47,190 --> 00:24:44,480
2008

599
00:24:48,070 --> 00:24:47,200
1995 one more time

600
00:24:51,029 --> 00:24:48,080
grow

601
00:24:53,510 --> 00:24:51,039
shrink

602
00:24:56,950 --> 00:24:53,520
yeah

603
00:24:59,269 --> 00:24:56,960
we are seeing this nebula grow on human

604
00:25:00,870 --> 00:24:59,279
time scales that usually doesn't happen

605
00:25:03,190 --> 00:25:00,880
okay

606
00:25:04,630 --> 00:25:03,200
and then if you trace that back to when

607
00:25:07,269 --> 00:25:04,640
it started

608
00:25:08,630 --> 00:25:07,279
well of course that is the time of the

609
00:25:10,830 --> 00:25:08,640
great eruption

610
00:25:15,029 --> 00:25:10,840
this nebula has been growing for about

611
00:25:17,430 --> 00:25:15,039
180 years since the 1840s that's when

612
00:25:20,870 --> 00:25:17,440
the humongous nebula was launched and

613
00:25:23,110 --> 00:25:20,880

exploded so this great eruption produced

614
00:25:24,789 --> 00:25:23,120
this homunculus nebula

615
00:25:26,390 --> 00:25:24,799
so let's go back to that light curve and

616
00:25:29,430 --> 00:25:26,400
try and understand it now that we know

617
00:25:32,149 --> 00:25:29,440
that the homologues nebula is there so

618
00:25:34,710 --> 00:25:32,159
in the 1840s it had the eruption and it

619
00:25:37,990 --> 00:25:34,720
started launching this nebula

620
00:25:39,990 --> 00:25:38,000
when the nebula was small it was dense

621
00:25:42,549 --> 00:25:40,000
and it blocked the light of the star and

622
00:25:44,070 --> 00:25:42,559
therefore the light of the star faded

623
00:25:46,230 --> 00:25:44,080
away

624
00:25:47,350 --> 00:25:46,240
then as the nebula gets larger and

625
00:25:49,110 --> 00:25:47,360
larger

626
00:25:50,710 --> 00:25:49,120
well you can start to seal through it a

627
00:25:53,510 --> 00:25:50,720
little bit it becomes less and less

628
00:25:55,590 --> 00:25:53,520
dense you can start to see through it

629
00:25:57,750 --> 00:25:55,600
and then the light of it a car starts

630
00:26:01,110 --> 00:25:57,760
coming through and the visible light

631
00:26:02,390 --> 00:26:01,120
starts to rise over the 20th century

632
00:26:05,190 --> 00:26:02,400
so the

633
00:26:07,350 --> 00:26:05,200
homunculus nebula explains the like this

634
00:26:10,230 --> 00:26:07,360
strange light curve at a car

635
00:26:11,430 --> 00:26:10,240
but what about this thing this lesser

636
00:26:13,750 --> 00:26:11,440
eruption

637
00:26:16,310 --> 00:26:13,760
did that also produce something

638
00:26:18,230 --> 00:26:16,320

well we can't see because we can't see

639
00:26:20,549 --> 00:26:18,240
through the homunculus nebula enough to

640
00:26:21,350 --> 00:26:20,559
actually see it at least with visible

641
00:26:22,230 --> 00:26:21,360
light

642
00:26:25,350 --> 00:26:22,240
but

643
00:26:26,950 --> 00:26:25,360
we can use spectroscopy to measure the

644
00:26:30,070 --> 00:26:26,960
velocity

645
00:26:32,230 --> 00:26:30,080
and this paper used a spectroscopy to

646
00:26:34,710 --> 00:26:32,240
measure the velocity of a molecular

647
00:26:36,870 --> 00:26:34,720
hydrogen deep inside the

648
00:26:38,470 --> 00:26:36,880
homunculus nebula

649
00:26:40,630 --> 00:26:38,480
and found and

650
00:26:41,830 --> 00:26:40,640
these velocity diagrams here are

651
00:26:43,190 --> 00:26:41,840
difficult to understand so i'm not going

652
00:26:45,350 --> 00:26:43,200
to try and explain

653
00:26:48,390 --> 00:26:45,360
but what they tell us

654
00:26:49,909 --> 00:26:48,400
is that there is a little homunculus

655
00:26:52,630 --> 00:26:49,919
nebula here

656
00:26:55,510 --> 00:26:52,640
and its shape in terms of a bipolar

657
00:26:58,230 --> 00:26:55,520
structure and its orientation along

658
00:27:00,710 --> 00:26:58,240
these diagonals are the same as the

659
00:27:03,269 --> 00:27:00,720
homunculus nebula

660
00:27:06,149 --> 00:27:03,279
the expansion time of this is actually

661
00:27:09,029 --> 00:27:06,159
is is consistent with the eruption from

662
00:27:11,590 --> 00:27:09,039
the 1890s it actually if you work it

663
00:27:12,549 --> 00:27:11,600

back it goes to about 1920

664
00:27:14,870 --> 00:27:12,559
but

665
00:27:16,950 --> 00:27:14,880
this little homunculus nebula material

666
00:27:19,430 --> 00:27:16,960
probably got pushed by the radiation

667
00:27:21,350 --> 00:27:19,440
pressure or stellar winds from the star

668
00:27:23,750 --> 00:27:21,360
which would speed it up

669
00:27:26,149 --> 00:27:23,760
okay and so actually it would have it's

670
00:27:30,789 --> 00:27:26,159
consistent with having been launched uh

671
00:27:32,149 --> 00:27:30,799
in the lesser eruption of the 1890s

672
00:27:34,950 --> 00:27:32,159
the other thing that knowing that the

673
00:27:38,870 --> 00:27:34,960
homicide scenario do is it explains why

674
00:27:40,710 --> 00:27:38,880
ada car is so bright in the infrared

675
00:27:42,950 --> 00:27:40,720
so this

676
00:27:45,269 --> 00:27:42,960
that gas and dust of the homunculus

677
00:27:47,669 --> 00:27:45,279
nebula blocked the light of the star and

678
00:27:50,630 --> 00:27:47,679
these massive stars which ada is a very

679
00:27:53,029 --> 00:27:50,640
massive star produce copious amounts of

680
00:27:55,110 --> 00:27:53,039
energetic light which is absorbed by the

681
00:27:58,230 --> 00:27:55,120
homunculus nebula and the gas in the

682
00:27:59,990 --> 00:27:58,240
dust inside it and re-radiated at

683
00:28:02,230 --> 00:28:00,000
infrared wavelengths

684
00:28:03,909 --> 00:28:02,240
so the reason why most the most massive

685
00:28:06,470 --> 00:28:03,919
stars aren't this really bright in the

686
00:28:08,870 --> 00:28:06,480
infrared but this one is so bright

687
00:28:11,669 --> 00:28:08,880
because the light is being reprocessed

688
00:28:14,070 --> 00:28:11,679

by the gas and dust within and along the

689
00:28:16,870 --> 00:28:14,080
surface along the outer parts of the

690
00:28:18,789 --> 00:28:16,880
homunculus nebula

691
00:28:21,430 --> 00:28:18,799
infrared is of course not the only

692
00:28:23,190 --> 00:28:21,440
wavelength we can use to explore it

693
00:28:26,149 --> 00:28:23,200
we have done multi-wavelength

694
00:28:27,909 --> 00:28:26,159
observations of the homunculus and the

695
00:28:29,750 --> 00:28:27,919
gas and dust around it

696
00:28:32,230 --> 00:28:29,760
and here we have a press release image

697
00:28:34,789 --> 00:28:32,240
that includes visible ultraviolet

698
00:28:36,549 --> 00:28:34,799
hydrogen alpha and x-ray and let me tell

699
00:28:37,750 --> 00:28:36,559
you a couple of things we learned from

700
00:28:41,350 --> 00:28:37,760
those

701
00:28:43,269 --> 00:28:41,360
uh if we look in ultraviolet light

702
00:28:45,909 --> 00:28:43,279
stars produ these massive stars produce

703
00:28:47,750 --> 00:28:45,919
tremendous amounts of ultraviolet light

704
00:28:50,710 --> 00:28:47,760
uh what we see is sort of some spiky

705
00:28:52,710 --> 00:28:50,720
emission through the tops of the lobes

706
00:28:55,110 --> 00:28:52,720
there's spikes that come out so it

707
00:28:57,350 --> 00:28:55,120
appears that it shows that the

708
00:28:59,750 --> 00:28:57,360
homunculus nebula has gotten become a

709
00:29:02,789 --> 00:28:59,760
bit porous and some of the light can

710
00:29:04,389 --> 00:29:02,799
escape from the star out through the top

711
00:29:07,590 --> 00:29:04,399
of the lobes

712
00:29:09,830 --> 00:29:07,600
we also see this equatorial mission

713
00:29:12,950 --> 00:29:09,840

these are spikes that come out from the

714
00:29:15,029 --> 00:29:12,960
center and they match up with the uh

715
00:29:17,029 --> 00:29:15,039
equatorial emission that we saw in

716
00:29:20,950 --> 00:29:17,039
visible light

717
00:29:24,630 --> 00:29:20,960
uh in hydrogen alpha this is

718
00:29:26,549 --> 00:29:24,640
a gas that's about 3000 degrees

719
00:29:29,110 --> 00:29:26,559
well this image is sort of processed

720
00:29:30,630 --> 00:29:29,120
just to to make the uh press release

721
00:29:33,750 --> 00:29:30,640
image but i want to show you one that's

722
00:29:36,870 --> 00:29:33,760
a little over saturated uh so you can

723
00:29:39,350 --> 00:29:36,880
see the details of this um

724
00:29:41,110 --> 00:29:39,360
of this hydrogen alpha emission because

725
00:29:42,070 --> 00:29:41,120
there's a lot of cool stuff going on in

726
00:29:43,909 --> 00:29:42,080
here

727
00:29:45,750 --> 00:29:43,919
and the first thing that i noticed is

728
00:29:47,909 --> 00:29:45,760
that well you've got this hydrogen alpha

729
00:29:50,149 --> 00:29:47,919
here that's been energized by the

730
00:29:54,310 --> 00:29:50,159
ultraviolet equatorial vision

731
00:29:56,230 --> 00:29:54,320
both here um and up here all right that

732
00:29:58,950 --> 00:29:56,240
you definitely see that the uv is

733
00:30:00,470 --> 00:29:58,960
heating this gas and causing it to glow

734
00:30:02,549 --> 00:30:00,480
but there's a lot of other stuff that's

735
00:30:04,789 --> 00:30:02,559
not associated with that

736
00:30:06,710 --> 00:30:04,799
um and so

737
00:30:10,070 --> 00:30:06,720
what is that stuff doing

738
00:30:12,549 --> 00:30:10,080

all right and so um there's a paper here

739
00:30:14,870 --> 00:30:12,559
that looked at the proper motion study

740
00:30:16,789 --> 00:30:14,880
of these knots out here

741
00:30:18,630 --> 00:30:16,799
where did this all this hydrogen alpha

742
00:30:19,430 --> 00:30:18,640
gas come from

743
00:30:21,350 --> 00:30:19,440
um

744
00:30:23,669 --> 00:30:21,360
and so they looked at the gas that's

745
00:30:24,870 --> 00:30:23,679
glowing in hydrogen alpha and nitrogen

746
00:30:27,510 --> 00:30:24,880
emission

747
00:30:29,350 --> 00:30:27,520
and they studied 800 of these little

748
00:30:32,070 --> 00:30:29,360
knots of gas

749
00:30:34,630 --> 00:30:32,080
using the 21 years of hst observations

750
00:30:35,909 --> 00:30:34,640
so you can follow you know 21 years

751
00:30:38,549 --> 00:30:35,919
apart is enough for them to actually

752
00:30:40,870 --> 00:30:38,559
move you can measure their proper motion

753
00:30:43,029 --> 00:30:40,880
and then deduce a velocity

754
00:30:45,510 --> 00:30:43,039
and the first thing you notice is that

755
00:30:48,230 --> 00:30:45,520
all of these vectors all of these arrows

756
00:30:51,430 --> 00:30:48,240
are pointing away from a to car

757
00:30:54,310 --> 00:30:51,440
so this stuff definitely came from hit a

758
00:30:55,350 --> 00:30:54,320
car it's flowing away and if you work

759
00:30:57,830 --> 00:30:55,360
back

760
00:31:01,110 --> 00:30:57,840
when that stuff started flowing away

761
00:31:02,830 --> 00:31:01,120
well the red stuff all these red arrows

762
00:31:04,710 --> 00:31:02,840
they come from the great eruption around

763
00:31:07,350 --> 00:31:04,720

1840

764
00:31:10,630 --> 00:31:07,360
the green arrows the stuff down here and

765
00:31:14,470 --> 00:31:10,640
the stuff up here those green arrows

766
00:31:16,630 --> 00:31:14,480
roughly come from around 1550

767
00:31:19,350 --> 00:31:16,640
and the blue stuff that's over here on

768
00:31:21,590 --> 00:31:19,360
the left side that stuff mainly comes

769
00:31:23,110 --> 00:31:21,600
from around 1250.

770
00:31:25,830 --> 00:31:23,120
so this is

771
00:31:27,830 --> 00:31:25,840
evidence that adacar has not just had

772
00:31:30,710 --> 00:31:27,840
the great eruption not just had the

773
00:31:33,269 --> 00:31:30,720
lesser eruption but has had at least two

774
00:31:35,509 --> 00:31:33,279
other significant eruptions uh in the

775
00:31:37,750 --> 00:31:35,519
last thousand years

776
00:31:39,830 --> 00:31:37,760
so this is a really um this is a star

777
00:31:42,470 --> 00:31:39,840
that's going to have multiple outbursts

778
00:31:44,950 --> 00:31:42,480
and one of the things you notice is that

779
00:31:47,269 --> 00:31:44,960
the blue stuff is all one-sided i mean

780
00:31:49,590 --> 00:31:47,279
there's no blue stuff over here on on

781
00:31:51,590 --> 00:31:49,600
the right okay

782
00:31:54,230 --> 00:31:51,600
and the green stuff seems to go up and

783
00:31:56,710 --> 00:31:54,240
down but not really left and right

784
00:31:59,669 --> 00:31:56,720
so they're different symmetries so these

785
00:32:00,950 --> 00:31:59,679
outbursts that occur roughly 300 years

786
00:32:05,909 --> 00:32:00,960
apart

787
00:32:10,389 --> 00:32:08,549
if we go on to the x-rays

788
00:32:12,710 --> 00:32:10,399

the first thing i need to tell you is

789
00:32:15,669 --> 00:32:12,720
that there's a lot of these small little

790
00:32:17,269 --> 00:32:15,679
dots that are not actually part of a ada

791
00:32:20,710 --> 00:32:17,279
car emission okay

792
00:32:23,750 --> 00:32:20,720
in x-rays we can see x-ray binaries and

793
00:32:24,630 --> 00:32:23,760
and galaxies point sources um so these

794
00:32:25,909 --> 00:32:24,640
are all

795
00:32:27,830 --> 00:32:25,919
a lot of those are just background

796
00:32:29,190 --> 00:32:27,840
sources it's mostly this the cloudy

797
00:32:31,430 --> 00:32:29,200
stuff here

798
00:32:33,110 --> 00:32:31,440
that is the stuff that comes from around

799
00:32:36,630 --> 00:32:33,120
ada carr

800
00:32:38,710 --> 00:32:36,640
and my first question on this was

801
00:32:40,870 --> 00:32:38,720
why are the x-rays

802
00:32:43,110 --> 00:32:40,880
on the outside

803
00:32:45,029 --> 00:32:43,120
i mean because

804
00:32:47,029 --> 00:32:45,039
if x-rays are the highest energy

805
00:32:49,830 --> 00:32:47,039
component that we're looking at here

806
00:32:52,630 --> 00:32:49,840
um and the energy source is deep down in

807
00:32:54,710 --> 00:32:52,640
the core right and so you'd expect the

808
00:32:56,870 --> 00:32:54,720
high energy stuff to be deep down in the

809
00:32:57,830 --> 00:32:56,880
core right next to the high the energy

810
00:33:00,470 --> 00:32:57,840
source

811
00:33:02,789 --> 00:33:00,480
but here we've got the highest energy

812
00:33:05,669 --> 00:33:02,799
stuff way on the outside

813
00:33:08,149 --> 00:33:05,679

and that had me scratching my head until

814
00:33:10,870 --> 00:33:08,159
i went and did some res some reading

815
00:33:13,190 --> 00:33:10,880
some papers and understanding all right

816
00:33:15,750 --> 00:33:13,200
and so the explanation for why the

817
00:33:19,029 --> 00:33:15,760
x-rays are out on the edge

818
00:33:21,590 --> 00:33:19,039
is due to shock heating it must be shock

819
00:33:25,830 --> 00:33:21,600
heating that there's fast ejecta moving

820
00:33:29,830 --> 00:33:25,840
out smashing into existing clouds and

821
00:33:32,950 --> 00:33:29,840
causing them to glow in x-rays okay a

822
00:33:36,470 --> 00:33:32,960
low density fast-moving ejecta that's

823
00:33:38,470 --> 00:33:36,480
creating um these high-energy emission

824
00:33:40,789 --> 00:33:38,480
and so we go back to that proper motion

825
00:33:43,269 --> 00:33:40,799
study that i just talked about

826
00:33:45,750 --> 00:33:43,279
and here we have those same vectors that

827
00:33:48,630 --> 00:33:45,760
were deduced for the um

828
00:33:51,350 --> 00:33:48,640
hydrogen alpha material of it overlaid

829
00:33:53,190 --> 00:33:51,360
on top of the x-ray image

830
00:33:55,669 --> 00:33:53,200
so the x-ray

831
00:33:58,549 --> 00:33:55,679
so so we're trying to find out what what

832
00:34:00,470 --> 00:33:58,559
when this fast-moving injector

833
00:34:02,149 --> 00:34:00,480
came was launched

834
00:34:04,870 --> 00:34:02,159
um and if you look at it you can see the

835
00:34:08,230 --> 00:34:04,880
blue stuff well that's generally outside

836
00:34:09,349 --> 00:34:08,240
of the x-ray glow

837
00:34:12,310 --> 00:34:09,359
it could be some of the blue stuff

838
00:34:14,470 --> 00:34:12,320

that's being ran into

839
00:34:16,310 --> 00:34:14,480
but it's not the source of the

840
00:34:17,669 --> 00:34:16,320
fast-moving injecta that's causing the

841
00:34:19,589 --> 00:34:17,679
x-rays

842
00:34:22,710 --> 00:34:19,599
same sort of thing for the the stuff

843
00:34:25,270 --> 00:34:22,720
from 1550 uh this green stuff up here

844
00:34:27,430 --> 00:34:25,280
that's outside of the x of the x-ray

845
00:34:29,750 --> 00:34:27,440
emission and this green stuff down here

846
00:34:31,909 --> 00:34:29,760
well that's actually in a whole of the

847
00:34:34,230 --> 00:34:31,919
x-ray emission there's no real x-rays

848
00:34:35,909 --> 00:34:34,240
being emitted down here so they don't

849
00:34:38,389 --> 00:34:35,919
seem correlated

850
00:34:41,909 --> 00:34:38,399
so the conclusion

851
00:34:44,629 --> 00:34:41,919
is that it this is fast-moving ejecta

852
00:34:47,669 --> 00:34:44,639
should have come from the

853
00:34:50,550 --> 00:34:47,679
great eruption in the 1840s

854
00:34:53,669 --> 00:34:50,560
that is also fits with the fact that the

855
00:34:56,629 --> 00:34:53,679
orientation this uh

856
00:35:00,069 --> 00:34:56,639
the elliptical axis of this is the same

857
00:35:02,310 --> 00:35:00,079
as the axis of the homunculus nebula so

858
00:35:04,710 --> 00:35:02,320
there's the same sort of shape or an

859
00:35:05,990 --> 00:35:04,720
orientation to the x-rays as the

860
00:35:09,670 --> 00:35:06,000
homunculus

861
00:35:12,470 --> 00:35:09,680
the problem is that the fast ejecta that

862
00:35:14,470 --> 00:35:12,480
would have come from the great eruption

863
00:35:16,390 --> 00:35:14,480

is not observed

864
00:35:18,230 --> 00:35:16,400
in this study they were looking for a

865
00:35:20,069 --> 00:35:18,240
material that's moving about a thousand

866
00:35:23,030 --> 00:35:20,079
kilometers a second

867
00:35:25,109 --> 00:35:23,040
and in order to create these x-rays

868
00:35:28,310 --> 00:35:25,119
the fast-moving stuff had to be moving

869
00:35:30,150 --> 00:35:28,320
about 3000 kilometers per second

870
00:35:31,750 --> 00:35:30,160
if you do the energetics that's how fast

871
00:35:33,589 --> 00:35:31,760
they need to be moving in order to

872
00:35:36,390 --> 00:35:33,599
excite these x-rays

873
00:35:37,430 --> 00:35:36,400
and so they could not see that with this

874
00:35:40,069 --> 00:35:37,440
study

875
00:35:42,310 --> 00:35:40,079
so there is more research to be done but

876
00:35:44,710 --> 00:35:42,320
the conclusion of this study is that

877
00:35:47,190 --> 00:35:44,720
there is a high energy fast moving

878
00:35:48,630 --> 00:35:47,200
component to the great eruption that we

879
00:35:51,190 --> 00:35:48,640
haven't seen

880
00:35:53,270 --> 00:35:51,200
but that is what's causing these x-rays

881
00:35:55,750 --> 00:35:53,280
and and and

882
00:35:58,390 --> 00:35:55,760
the x-ray emissions when it plows into

883
00:36:01,750 --> 00:35:58,400
pre-existing clouds

884
00:36:02,870 --> 00:36:01,760
and creates the x-ray emission

885
00:36:04,710 --> 00:36:02,880
so

886
00:36:06,630 --> 00:36:04,720
here is the

887
00:36:08,710 --> 00:36:06,640
composite of it where we've got the

888
00:36:11,349 --> 00:36:08,720

x-rays on the outside you've got the

889
00:36:12,790 --> 00:36:11,359
hydrogen alpha here you've got the

890
00:36:14,630 --> 00:36:12,800
ultraviolet here and you've got the

891
00:36:16,550 --> 00:36:14,640
visible light here

892
00:36:18,390 --> 00:36:16,560
and i will note that you can see the

893
00:36:20,950 --> 00:36:18,400
interaction between the ultraviolet

894
00:36:24,069 --> 00:36:20,960
hitting the hydrogen alpha here and then

895
00:36:25,510 --> 00:36:24,079
again up in here which is really kind of

896
00:36:26,870 --> 00:36:25,520
cool you know see the connections

897
00:36:29,190 --> 00:36:26,880
between these things

898
00:36:30,870 --> 00:36:29,200
and this is really a lot of interesting

899
00:36:33,589 --> 00:36:30,880
structure and you might ask yourself can

900
00:36:35,510 --> 00:36:33,599
one star really do all this

901
00:36:39,510 --> 00:36:35,520
uh the answer is no

902
00:36:42,230 --> 00:36:39,520
one star can't do it but two stars well

903
00:36:44,710 --> 00:36:42,240
that's what we think has got going on

904
00:36:46,630 --> 00:36:44,720
because when you go in and investigate

905
00:36:49,750 --> 00:36:46,640
the ada car system

906
00:36:50,870 --> 00:36:49,760
you find that it is a double star system

907
00:36:51,910 --> 00:36:50,880
with one

908
00:36:54,470 --> 00:36:51,920
really

909
00:36:56,310 --> 00:36:54,480
huge star a 100 so about 100 solar

910
00:36:57,750 --> 00:36:56,320
masses

911
00:37:00,470 --> 00:36:57,760
and one

912
00:37:01,349 --> 00:37:00,480
large star about 30 solar masses both of

913
00:37:04,069 --> 00:37:01,359

these

914
00:37:06,470 --> 00:37:04,079
are really really big stars okay

915
00:37:09,030 --> 00:37:06,480
but they're in a binary system and here

916
00:37:11,829 --> 00:37:09,040
is the orbit on the right hand side

917
00:37:14,230 --> 00:37:11,839
that's a very elongated orbit but it

918
00:37:15,750 --> 00:37:14,240
only takes five and a half years for

919
00:37:18,150 --> 00:37:15,760
them to make their orbit

920
00:37:21,109 --> 00:37:18,160
so we think of the small star orbiting

921
00:37:25,349 --> 00:37:21,119
around the big star and every five and a

922
00:37:28,630 --> 00:37:25,359
half years it comes in um past it

923
00:37:30,630 --> 00:37:28,640
now this is what they call a colliding

924
00:37:31,990 --> 00:37:30,640
wind binary

925
00:37:34,630 --> 00:37:32,000
because

926
00:37:37,470 --> 00:37:34,640
these massive stars have

927
00:37:41,270 --> 00:37:37,480
giant stellar winds they produce

928
00:37:43,750 --> 00:37:41,280
incredible stellar winds uh you saw how

929
00:37:45,270 --> 00:37:43,760
a car stellar stellar wind streamed

930
00:37:46,550 --> 00:37:45,280
across the korean nebula and created

931
00:37:49,030 --> 00:37:46,560
those pillars

932
00:37:52,390 --> 00:37:49,040
well that 15 that 30 solar mass star

933
00:37:55,829 --> 00:37:52,400
also has a very strong solar wind okay

934
00:37:58,069 --> 00:37:55,839
and when it is at ap astron which means

935
00:37:59,270 --> 00:37:58,079
the farthest point in the in

936
00:38:02,550 --> 00:37:59,280
in the orbit

937
00:38:06,069 --> 00:38:02,560
um the the winds are winds

938
00:38:08,870 --> 00:38:06,079

they interact a little bit but not much

939
00:38:11,430 --> 00:38:08,880
but bring that star that that star in

940
00:38:14,150 --> 00:38:11,440
close to periastron the closest point in

941
00:38:16,150 --> 00:38:14,160
their orbits um and then those winds

942
00:38:19,829 --> 00:38:16,160
interact strongly

943
00:38:23,270 --> 00:38:19,839
and they will produce x-rays

944
00:38:25,910 --> 00:38:23,280
and we have evidence of all this

945
00:38:27,670 --> 00:38:25,920
in one of the most gorgeous plots i've

946
00:38:31,750 --> 00:38:27,680
seen in a long time

947
00:38:34,870 --> 00:38:31,760
this is the x-ray light curve of ada car

948
00:38:37,670 --> 00:38:34,880
so using several different um x-ray

949
00:38:39,829 --> 00:38:37,680
instruments um you can see over every

950
00:38:40,630 --> 00:38:39,839
five and a half years there's a giant

951
00:38:44,230 --> 00:38:40,640
peak

952
00:38:46,950 --> 00:38:44,240
in the x-ray emission from adacar as

953
00:38:49,750 --> 00:38:46,960
these two stars come in close together

954
00:38:51,030 --> 00:38:49,760
the winds collide they produce copious

955
00:38:53,829 --> 00:38:51,040
x-rays

956
00:38:56,470 --> 00:38:53,839
and you've got this uh this big emission

957
00:38:57,990 --> 00:38:56,480
so this is what's going on in the core

958
00:39:00,870 --> 00:38:58,000
you've got a

959
00:39:04,550 --> 00:39:00,880
colliding wind binary system

960
00:39:05,670 --> 00:39:04,560
that is the genesis of all of this stuff

961
00:39:07,910 --> 00:39:05,680
so

962
00:39:10,069 --> 00:39:07,920
you then ask yourself all right well

963
00:39:12,310 --> 00:39:10,079

this is a great eruption and you know

964
00:39:14,630 --> 00:39:12,320
really

965
00:39:16,390 --> 00:39:14,640
how did it happen okay

966
00:39:19,750 --> 00:39:16,400
um so first of all let me just talk to

967
00:39:22,230 --> 00:39:19,760
about why it's a great eruption okay um

968
00:39:24,310 --> 00:39:22,240
ada car a the large star

969
00:39:28,069 --> 00:39:24,320
lost about 10

970
00:39:31,270 --> 00:39:28,079
of its mass okay 10 of the star blow out

971
00:39:34,310 --> 00:39:31,280
that's 10 to 20 solar masses

972
00:39:35,430 --> 00:39:34,320
blowing out in one event that's a huge

973
00:39:37,750 --> 00:39:35,440
event

974
00:39:40,150 --> 00:39:37,760
uh the total energy ends uh the

975
00:39:42,870 --> 00:39:40,160
radiation from it as well as the kinetic

976
00:39:45,589 --> 00:39:42,880
energy of the material flowing out

977
00:39:46,710 --> 00:39:45,599
is about ten percent of a supernova

978
00:39:51,750 --> 00:39:46,720
explosion

979
00:39:54,390 --> 00:39:51,760
you know blows in a star apart it uses

980
00:39:56,069 --> 00:39:54,400
about 10 to the 51 herbs this one if you

981
00:39:57,430 --> 00:39:56,079
add everything together it's about 10 to

982
00:40:00,150 --> 00:39:57,440
the 50th

983
00:40:02,230 --> 00:40:00,160
herbs of that so this is a credible

984
00:40:05,030 --> 00:40:02,240
amount of energy

985
00:40:07,109 --> 00:40:05,040
and also when you look at the energetics

986
00:40:09,430 --> 00:40:07,119
you almost you sort of get violations of

987
00:40:10,390 --> 00:40:09,440
what's called the eddington limit

988
00:40:11,990 --> 00:40:10,400

um i

989
00:40:12,790 --> 00:40:12,000
don't want to go into too much detail

990
00:40:14,710 --> 00:40:12,800
here

991
00:40:16,950 --> 00:40:14,720
but if you

992
00:40:19,589 --> 00:40:16,960
use physics to figure out what is the

993
00:40:22,309 --> 00:40:19,599
mass what is the the the

994
00:40:25,829 --> 00:40:22,319
maximum amount of energy that a star can

995
00:40:28,390 --> 00:40:25,839
release okay using basic physics of of

996
00:40:29,750 --> 00:40:28,400
radiation and and and pressure and such

997
00:40:32,470 --> 00:40:29,760
um you get something called the

998
00:40:35,109 --> 00:40:32,480
eddington limit and the energetics of

999
00:40:36,630 --> 00:40:35,119
this great eruption

1000
00:40:39,190 --> 00:40:36,640
kind of look like they violate the

1001
00:40:41,750 --> 00:40:39,200
eddington limit and if it gets super

1002
00:40:43,910 --> 00:40:41,760
eddington luminosity here uh you got to

1003
00:40:46,230 --> 00:40:43,920
figure out why and there's got to be a

1004
00:40:48,309 --> 00:40:46,240
reason why it really can't violate the

1005
00:40:50,069 --> 00:40:48,319
eddington limit because that's due to

1006
00:40:52,470 --> 00:40:50,079
physics but

1007
00:40:54,309 --> 00:40:52,480
there's an awful if depending upon what

1008
00:40:56,870 --> 00:40:54,319
you think is the mechanism it sort of

1009
00:40:59,270 --> 00:40:56,880
does violate the eddington limit so it's

1010
00:41:00,550 --> 00:40:59,280
this is what makes it really great

1011
00:41:02,790 --> 00:41:00,560
so you got to consider the physics

1012
00:41:05,510 --> 00:41:02,800
that's going on here okay you've got two

1013
00:41:07,349 --> 00:41:05,520

very massive stars okay and down in

1014
00:41:10,230 --> 00:41:07,359
their cores they have nuclear fusion

1015
00:41:12,390 --> 00:41:10,240
that's providing the the the energy that

1016
00:41:14,390 --> 00:41:12,400
that's powering these stars and they're

1017
00:41:16,710 --> 00:41:14,400
they're they're the nuclear fusion is

1018
00:41:19,030 --> 00:41:16,720
going on at a prodigious rate

1019
00:41:22,230 --> 00:41:19,040
um that energy that's created in the

1020
00:41:24,710 --> 00:41:22,240
core goes out through the star

1021
00:41:26,470 --> 00:41:24,720
in various various ways

1022
00:41:27,829 --> 00:41:26,480
conduction convection

1023
00:41:29,510 --> 00:41:27,839
and radiation

1024
00:41:32,230 --> 00:41:29,520
and the convective layers are this

1025
00:41:34,470 --> 00:41:32,240
overturning of material hot material

1026
00:41:37,030 --> 00:41:34,480
rises cool material goes down it's

1027
00:41:40,870 --> 00:41:37,040
overturning in these convective zones

1028
00:41:43,670 --> 00:41:40,880
that can cause that can be quite

1029
00:41:45,510 --> 00:41:43,680
violent and a little bit unstable

1030
00:41:48,069 --> 00:41:45,520
then when you get out to the photosphere

1031
00:41:50,870 --> 00:41:48,079
you release all this radiation that

1032
00:41:53,430 --> 00:41:50,880
actually has pressure associated um you

1033
00:41:55,910 --> 00:41:53,440
know radiation pressure can push things

1034
00:41:57,430 --> 00:41:55,920
can push gas clouds and everything

1035
00:41:58,870 --> 00:41:57,440
and then of course you've got stellar

1036
00:42:01,670 --> 00:41:58,880
winds which these are the charged

1037
00:42:03,829 --> 00:42:01,680
particles streaming away from the stars

1038
00:42:06,309 --> 00:42:03,839

at you know amazing rates

1039
00:42:08,069 --> 00:42:06,319
for these massive stars so those are the

1040
00:42:10,550 --> 00:42:08,079
physics involved

1041
00:42:12,870 --> 00:42:10,560
and there are several hypotheses as to

1042
00:42:15,190 --> 00:42:12,880
what caused the great eruption

1043
00:42:17,589 --> 00:42:15,200
yeah these are just hypotheses because

1044
00:42:19,990 --> 00:42:17,599
we do not know which one

1045
00:42:21,910 --> 00:42:20,000
is correct or if indeed if any of them

1046
00:42:24,309 --> 00:42:21,920
are correct all right

1047
00:42:26,150 --> 00:42:24,319
so it basically involves variations of

1048
00:42:28,390 --> 00:42:26,160
all the physics okay

1049
00:42:30,069 --> 00:42:28,400
radiation pressure and dynamical

1050
00:42:33,270 --> 00:42:30,079
instabilities so the dynamical

1051
00:42:35,190 --> 00:42:33,280
instability is probably due to the

1052
00:42:37,750 --> 00:42:35,200
invective things and the radiation

1053
00:42:39,910 --> 00:42:37,760
pressure end up pushing the outer layers

1054
00:42:42,069 --> 00:42:39,920
of the star off

1055
00:42:44,309 --> 00:42:42,079
or they could be gravity mode

1056
00:42:46,710 --> 00:42:44,319
instabilities and i will be honest with

1057
00:42:49,430 --> 00:42:46,720
you i did not truly understand what's

1058
00:42:50,790 --> 00:42:49,440
going on here um in in this in this

1059
00:42:51,750 --> 00:42:50,800
description so i'm just going to leave

1060
00:42:54,069 --> 00:42:51,760
it that you know there are some

1061
00:42:56,870 --> 00:42:54,079
gravitational fluctuations uh that can

1062
00:42:58,950 --> 00:42:56,880
go unstable and help cause the

1063
00:43:01,510 --> 00:42:58,960

outer layers to go off

1064
00:43:04,710 --> 00:43:01,520
another hypothesis i read about was a

1065
00:43:06,630 --> 00:43:04,720
scaled down supernova explosion so this

1066
00:43:09,670 --> 00:43:06,640
must involve something of the nuclear

1067
00:43:13,670 --> 00:43:09,680
fusion that's going on inside the star

1068
00:43:15,430 --> 00:43:13,680
and the explosion only goes so far blows

1069
00:43:17,510 --> 00:43:15,440
off the outer layers but doesn't blow

1070
00:43:19,670 --> 00:43:17,520
the star apart

1071
00:43:21,910 --> 00:43:19,680
and finally one of the more inventive

1072
00:43:25,430 --> 00:43:21,920
hypotheses i read about

1073
00:43:28,309 --> 00:43:25,440
was a merger in a triple star system

1074
00:43:30,790 --> 00:43:28,319
so ada car a and ada car b have a binary

1075
00:43:32,230 --> 00:43:30,800
system now but what if there was an ada

1076
00:43:34,550 --> 00:43:32,240
car c

1077
00:43:37,190 --> 00:43:34,560
that was orbiting around this and

1078
00:43:41,030 --> 00:43:37,200
actually came in and got

1079
00:43:43,510 --> 00:43:41,040
got caught up and merged with ada car a

1080
00:43:45,829 --> 00:43:43,520
and they show that that could possibly

1081
00:43:47,270 --> 00:43:45,839
provide the energy that produces the

1082
00:43:49,990 --> 00:43:47,280
great eruption

1083
00:43:53,349 --> 00:43:50,000
now unfortunately when there's evidence

1084
00:43:57,750 --> 00:43:53,359
that there were also eruptions in um

1085
00:44:00,630 --> 00:43:57,760
1550 and in around 1250 um this merger

1086
00:44:03,589 --> 00:44:00,640
hypothesis is a little sketchy because

1087
00:44:06,870 --> 00:44:03,599
well what happened at those times right

1088
00:44:09,190 --> 00:44:06,880

i don't know uh as i say i'm not an

1089
00:44:11,030 --> 00:44:09,200
expert in the

1090
00:44:13,109 --> 00:44:11,040
edicar research

1091
00:44:15,670 --> 00:44:13,119
i really enjoy reading about it but i

1092
00:44:17,910 --> 00:44:15,680
can only say that this is an active

1093
00:44:21,190 --> 00:44:17,920
research topic

1094
00:44:22,550 --> 00:44:21,200
so what i am expert in is astronomy

1095
00:44:25,910 --> 00:44:22,560
visualization

1096
00:44:28,069 --> 00:44:25,920
and i'm the lead on the astroviz project

1097
00:44:29,190 --> 00:44:28,079
that is part of nasa's universe of

1098
00:44:33,750 --> 00:44:29,200
learning

1099
00:44:37,030 --> 00:44:33,760
among four institutions the space

1100
00:44:39,109 --> 00:44:37,040
telescope science institute caltech ipac

1101
00:44:41,349 --> 00:44:39,119
the jet propulsion laboratory and the

1102
00:44:42,950 --> 00:44:41,359
center for astrophysics harvard and

1103
00:44:46,630 --> 00:44:42,960
smithsonian

1104
00:44:50,309 --> 00:44:46,640
and the astroviz project has as its goal

1105
00:44:52,950 --> 00:44:50,319
to create visualizations of astronomical

1106
00:44:55,990 --> 00:44:52,960
things using multi-wavelength data from

1107
00:44:58,790 --> 00:44:56,000
nasa in order to present

1108
00:45:00,470 --> 00:44:58,800
learning messages to the public

1109
00:45:03,430 --> 00:45:00,480
all right and as you can see here we

1110
00:45:05,270 --> 00:45:03,440
have done the orion nebula invisible and

1111
00:45:06,950 --> 00:45:05,280
infrared light we have done the

1112
00:45:10,390 --> 00:45:06,960
whirlpool galaxy

1113
00:45:12,390 --> 00:45:10,400

in infrared visible and x-ray uh we have

1114
00:45:14,230 --> 00:45:12,400
done visible infrared and x-ray of the

1115
00:45:17,349 --> 00:45:14,240
crab nebula

1116
00:45:20,150 --> 00:45:17,359
and we've also released the video going

1117
00:45:22,309 --> 00:45:20,160
through the ultra deep field

1118
00:45:24,710 --> 00:45:22,319
so we have done these large-scale

1119
00:45:27,750 --> 00:45:24,720
cinematic visualization projects

1120
00:45:29,990 --> 00:45:27,760
and for last year we chose to do

1121
00:45:31,030 --> 00:45:30,000
edicarinate

1122
00:45:35,270 --> 00:45:31,040
so

1123
00:45:37,349 --> 00:45:35,280
of this model now first of all there is

1124
00:45:39,270 --> 00:45:37,359
pre-existing models of the homunculus

1125
00:45:42,309 --> 00:45:39,280
nebula researchers have been looking

1126
00:45:43,670 --> 00:45:42,319
this for decades and decades so of

1127
00:45:46,390 --> 00:45:43,680
course they have ideas and it's

1128
00:45:48,550 --> 00:45:46,400
basically you know two big bubbles right

1129
00:45:50,550 --> 00:45:48,560
it's an hourglass shape and so this was

1130
00:45:53,990 --> 00:45:50,560
the latest model that came out in

1131
00:45:56,309 --> 00:45:54,000
somewhere around 2015 2016 time frame

1132
00:45:59,030 --> 00:45:56,319
from my friend wolfgang steffen working

1133
00:46:01,829 --> 00:45:59,040
with a bunch of collaborators

1134
00:46:04,630 --> 00:46:01,839
a scientific collaborators um and they

1135
00:46:07,109 --> 00:46:04,640
got the the basics of it based upon some

1136
00:46:08,790 --> 00:46:07,119
velocity information about it

1137
00:46:10,950 --> 00:46:08,800
and there are unfortunately two things i

1138
00:46:13,829 --> 00:46:10,960

didn't like about this model for use in

1139
00:46:16,470 --> 00:46:13,839
our things uh the first thing is that

1140
00:46:18,710 --> 00:46:16,480
these protrusions here okay

1141
00:46:21,270 --> 00:46:18,720
um are supposed to match these

1142
00:46:23,829 --> 00:46:21,280
protrusions here in the dusker what i

1143
00:46:25,750 --> 00:46:23,839
call the equatorial emission

1144
00:46:28,390 --> 00:46:25,760
and one of their results was that these

1145
00:46:30,470 --> 00:46:28,400
protrusions were tilted that this one

1146
00:46:31,910 --> 00:46:30,480
was going away from us and this one was

1147
00:46:34,470 --> 00:46:31,920
coming towards us

1148
00:46:37,190 --> 00:46:34,480
and when we were talked with our expert

1149
00:46:39,190 --> 00:46:37,200
and looked at the 3d modeling of it and

1150
00:46:40,470 --> 00:46:39,200
particularly also in when we were using

1151
00:46:42,950 --> 00:46:40,480
ultraviolet

1152
00:46:45,510 --> 00:46:42,960
it didn't seem to work so

1153
00:46:47,750 --> 00:46:45,520
we changed it and we put those in the uh

1154
00:46:49,430 --> 00:46:47,760
uh equatorial plane

1155
00:46:51,430 --> 00:46:49,440
the second thing we didn't like about it

1156
00:46:54,069 --> 00:46:51,440
is that it's orange

1157
00:46:56,790 --> 00:46:54,079
you know i mean the homunculus nebula is

1158
00:46:58,309 --> 00:46:56,800
an orange and so the most important

1159
00:47:00,470 --> 00:46:58,319
thing we did

1160
00:47:03,670 --> 00:47:00,480
in improving their model

1161
00:47:05,750 --> 00:47:03,680
was to create that surface texture

1162
00:47:08,790 --> 00:47:05,760
and so here is some of the texture

1163
00:47:12,150 --> 00:47:08,800

development we did this was done by one

1164
00:47:14,309 --> 00:47:12,160
of our amazing artists danny player

1165
00:47:16,230 --> 00:47:14,319
and you can see it started out looking

1166
00:47:19,109 --> 00:47:16,240
somewhat like a paper lantern it was a

1167
00:47:22,150 --> 00:47:19,119
very thin layer and getting through

1168
00:47:23,750 --> 00:47:22,160
and she had lots of small scale noise

1169
00:47:25,990 --> 00:47:23,760
we used something called noise in

1170
00:47:29,030 --> 00:47:26,000
computer graphics to create these random

1171
00:47:31,510 --> 00:47:29,040
patterns to try and you know

1172
00:47:34,309 --> 00:47:31,520
replicate or not not exactly replicate

1173
00:47:36,549 --> 00:47:34,319
but mimic the feel look and feel of the

1174
00:47:37,510 --> 00:47:36,559
eda car and then she added in lots of

1175
00:47:40,470 --> 00:47:37,520
high

1176
00:47:43,510 --> 00:47:40,480
larger scale noise and you know dialed

1177
00:47:44,390 --> 00:47:43,520
it back a bit until we get to our final

1178
00:47:46,309 --> 00:47:44,400
view

1179
00:47:49,109 --> 00:47:46,319
which is like this

1180
00:47:51,190 --> 00:47:49,119
um so creating the the bulbs of a

1181
00:47:53,589 --> 00:47:51,200
homunculus nebula and getting that

1182
00:47:54,950 --> 00:47:53,599
surface texture to look and feel like

1183
00:47:57,750 --> 00:47:54,960
the um

1184
00:47:59,589 --> 00:47:57,760
well like the actual homunculus nebula

1185
00:48:01,349 --> 00:47:59,599
here is actually the final which comes

1186
00:48:03,349 --> 00:48:01,359
out of the composite

1187
00:48:05,349 --> 00:48:03,359
we render things and we go into a

1188
00:48:07,349 --> 00:48:05,359

compositing program where we can adjust

1189
00:48:09,510 --> 00:48:07,359
colors we can you know brighten and

1190
00:48:11,670 --> 00:48:09,520
highlight and work on this so we can

1191
00:48:13,430 --> 00:48:11,680
adjust it after we've already rendered

1192
00:48:15,270 --> 00:48:13,440
the 3d model

1193
00:48:17,190 --> 00:48:15,280
and if you turn this sideways you can

1194
00:48:19,589 --> 00:48:17,200
see here are the protrusions that we put

1195
00:48:22,470 --> 00:48:19,599
in the equatorial plane

1196
00:48:23,750 --> 00:48:22,480
i also asked danny to put in a third

1197
00:48:24,549 --> 00:48:23,760
protrusion

1198
00:48:26,950 --> 00:48:24,559
um

1199
00:48:28,549 --> 00:48:26,960
just for sort of symmetry in 3d when we

1200
00:48:30,390 --> 00:48:28,559
spun this around in 3d we just used

1201
00:48:34,069 --> 00:48:30,400
those two protrusions it felt kind of

1202
00:48:36,630 --> 00:48:34,079
lopsided so i took artistic license

1203
00:48:38,790 --> 00:48:36,640
and we added a protrusion that actually

1204
00:48:41,750 --> 00:48:38,800
goes out the back so you we can't see it

1205
00:48:44,470 --> 00:48:41,760
from earth so if it if it exists um

1206
00:48:46,950 --> 00:48:44,480
great uh it probably doesn't exist but

1207
00:48:48,710 --> 00:48:46,960
just for the 3d look and feel we added

1208
00:48:52,309 --> 00:48:48,720
it uh to

1209
00:48:55,430 --> 00:48:52,319
for for artistic purposes

1210
00:48:57,030 --> 00:48:55,440
then um we go on to the ultraviolet all

1211
00:48:58,309 --> 00:48:57,040
right and as we talked about previously

1212
00:49:00,470 --> 00:48:58,319
in the ultraviolet that we have the

1213
00:49:01,990 --> 00:49:00,480

equatorial spikes here

1214
00:49:03,910 --> 00:49:02,000
we have the spikes that come out the

1215
00:49:05,829 --> 00:49:03,920
tops of the lobes

1216
00:49:08,150 --> 00:49:05,839
and then when there's just a little bit

1217
00:49:10,069 --> 00:49:08,160
of haze that works around there

1218
00:49:12,630 --> 00:49:10,079
all right and then you composite that on

1219
00:49:13,829 --> 00:49:12,640
top of the homunculus nebula as done in

1220
00:49:17,030 --> 00:49:13,839
visible light

1221
00:49:19,109 --> 00:49:17,040
so there is no ultraviolet light model

1222
00:49:21,030 --> 00:49:19,119
it's really the visible light model and

1223
00:49:24,069 --> 00:49:21,040
then the ultraviolet light added on top

1224
00:49:26,309 --> 00:49:24,079
of it so we're building layer upon layer

1225
00:49:28,150 --> 00:49:26,319
in this model

1226
00:49:30,230 --> 00:49:28,160
hydrogen alpha

1227
00:49:32,390 --> 00:49:30,240
again it's all this cloudy stuff that's

1228
00:49:34,950 --> 00:49:32,400
further out and we had to correlate with

1229
00:49:36,950 --> 00:49:34,960
the um ultraviolet um here is the

1230
00:49:38,790 --> 00:49:36,960
hydrogen alpha render oh you'll also

1231
00:49:41,829 --> 00:49:38,800
notice that these renders are in black

1232
00:49:44,069 --> 00:49:41,839
and white um that's because the color

1233
00:49:46,630 --> 00:49:44,079
actually gets added in the composite

1234
00:49:49,510 --> 00:49:46,640
there's no need to add color um in in

1235
00:49:50,950 --> 00:49:49,520
the render we can just do all that in

1236
00:49:52,630 --> 00:49:50,960
when we do the comp

1237
00:49:56,150 --> 00:49:52,640
all right and so here is the hydrogen

1238
00:49:59,589 --> 00:49:56,160

alpha multi-layered adjusted smooth i'll

1239
00:50:02,549 --> 00:49:59,599
put on top of that um and then we do the

1240
00:50:05,510 --> 00:50:02,559
x-rays uh i'm gonna blow up i blowed up

1241
00:50:08,870 --> 00:50:05,520
blew up the x-ray light model here so

1242
00:50:11,990 --> 00:50:08,880
you can see another feature of our of

1243
00:50:14,710 --> 00:50:12,000
our modeling is that this is the visible

1244
00:50:17,750 --> 00:50:14,720
light homunculus nebula here

1245
00:50:20,710 --> 00:50:17,760
and when we render the outer layers

1246
00:50:24,309 --> 00:50:20,720
we need to put that in as a solid black

1247
00:50:26,710 --> 00:50:24,319
object okay call it a 3d matte so that

1248
00:50:29,430 --> 00:50:26,720
the light that would be on the far side

1249
00:50:31,910 --> 00:50:29,440
of the homunculus doesn't appear in the

1250
00:50:33,430 --> 00:50:31,920
render so as we're as we're rotating

1251
00:50:35,030 --> 00:50:33,440
around it

1252
00:50:37,109 --> 00:50:35,040
that will block all the light from the

1253
00:50:38,309 --> 00:50:37,119
far side and only the flight that you

1254
00:50:42,390 --> 00:50:38,319
can see

1255
00:50:45,030 --> 00:50:42,400
all right and so here is the x-ray model

1256
00:50:47,270 --> 00:50:45,040
and then the composite onto all this

1257
00:50:50,069 --> 00:50:47,280
where we get the full thing

1258
00:50:51,270 --> 00:50:50,079
so here are the 3d model layers the

1259
00:50:53,589 --> 00:50:51,280
homunculus

1260
00:50:56,790 --> 00:50:53,599
adding the ultraviolet adding the h

1261
00:50:59,430 --> 00:50:56,800
alpha and adding the x-ray to give us

1262
00:51:01,910 --> 00:50:59,440
this full multi-wavelength view of these

1263
00:51:05,270 --> 00:51:01,920

really cool structures

1264
00:51:07,109 --> 00:51:05,280
still there's one more wavelength

1265
00:51:09,510 --> 00:51:07,119
that infrared

1266
00:51:13,430 --> 00:51:09,520
alright in which we wanted to show off

1267
00:51:16,309 --> 00:51:13,440
how bright adacar is in the infrared

1268
00:51:18,950 --> 00:51:16,319
so this is the spitzer image

1269
00:51:21,670 --> 00:51:18,960
and you'll notice it's got a ton of

1270
00:51:23,430 --> 00:51:21,680
stars and what we really want to model

1271
00:51:25,190 --> 00:51:23,440
is the nebula here

1272
00:51:28,549 --> 00:51:25,200
there will be stars but we got to get

1273
00:51:29,589 --> 00:51:28,559
rid of those and so

1274
00:51:30,790 --> 00:51:29,599
boom

1275
00:51:32,309 --> 00:51:30,800
there you go

1276
00:51:35,589 --> 00:51:32,319
goodbye stars

1277
00:51:36,390 --> 00:51:35,599
that's a tremendous amount of photoshop

1278
00:51:39,750 --> 00:51:36,400
work

1279
00:51:43,990 --> 00:51:39,760
uh done by uh one of our our artists

1280
00:51:46,549 --> 00:51:44,000
probably alisa pagan um just amazing

1281
00:51:49,270 --> 00:51:46,559
stuff to get rid of all all those stars

1282
00:51:50,710 --> 00:51:49,280
and leave us with this uh surface of the

1283
00:51:52,069 --> 00:51:50,720
nebula

1284
00:51:54,309 --> 00:51:52,079
we then

1285
00:51:57,030 --> 00:51:54,319
take that surface of the nebula and we

1286
00:51:59,670 --> 00:51:57,040
analyze it for its 3d structure

1287
00:52:02,150 --> 00:51:59,680
what stuff is furthest away from us what

1288
00:52:04,549 --> 00:52:02,160

stuff is a little closer a little closer

1289
00:52:06,549 --> 00:52:04,559
and all the way further forward

1290
00:52:09,190 --> 00:52:06,559
so what we created here is what we call

1291
00:52:12,150 --> 00:52:09,200
a decoupage model a sculpted decoupage

1292
00:52:14,470 --> 00:52:12,160
model so here is um

1293
00:52:17,430 --> 00:52:14,480
leah hustak's

1294
00:52:20,150 --> 00:52:17,440
analysis of this working with myself and

1295
00:52:23,349 --> 00:52:20,160
robert hurt to try and analyze which

1296
00:52:26,549 --> 00:52:23,359
layers are where in in 3d relation

1297
00:52:29,829 --> 00:52:26,559
and here is the 3d model with the camera

1298
00:52:32,870 --> 00:52:29,839
representing um the earth viewpoint

1299
00:52:35,030 --> 00:52:32,880
and the three the 3d the layers all

1300
00:52:38,069 --> 00:52:35,040
being these you know flat layers that

1301
00:52:40,549 --> 00:52:38,079
are then sculpted into into small shapes

1302
00:52:43,670 --> 00:52:40,559
to produce the illusion of a full 3d

1303
00:52:45,190 --> 00:52:43,680
model as the camera backs out

1304
00:52:46,870 --> 00:52:45,200
and you may think to yourself well come

1305
00:52:48,230 --> 00:52:46,880
on flat layers that's not going to

1306
00:52:49,589 --> 00:52:48,240
convince me

1307
00:52:52,549 --> 00:52:49,599
yeah you're wrong

1308
00:52:54,390 --> 00:52:52,559
it does convince you it's really uh it's

1309
00:52:56,150 --> 00:52:54,400
an enough a technique that's much more

1310
00:52:57,190 --> 00:52:56,160
effective than it really has any right

1311
00:53:01,349 --> 00:52:57,200
to be

1312
00:53:04,950 --> 00:53:01,359
okay so now we get to our movie

1313
00:53:08,230 --> 00:53:04,960

okay and the movie is incarnate the

1314
00:53:11,030 --> 00:53:08,240
great eruption of a massive star

1315
00:53:13,990 --> 00:53:11,040
um and i put the um

1316
00:53:17,030 --> 00:53:14,000
wonderful visualization team um joe

1317
00:53:20,150 --> 00:53:17,040
olmstead who did the ultraviolet the

1318
00:53:21,829 --> 00:53:20,160
hydrogen alpha and the x-ray layers uh

1319
00:53:23,910 --> 00:53:21,839
danny player who did the homunculus

1320
00:53:27,670 --> 00:53:23,920
layer leo stack who did compositing the

1321
00:53:30,230 --> 00:53:27,680
infrared uh alisa pagan and

1322
00:53:33,190 --> 00:53:30,240
who did the 2d image processing greg

1323
00:53:35,910 --> 00:53:33,200
bacon who's the producer myself and

1324
00:53:37,910 --> 00:53:35,920
robert hurt who worked on the infrared

1325
00:53:39,829 --> 00:53:37,920
um i can't thank them enough don't give

1326
00:53:42,470 --> 00:53:39,839
me the all the credit i was just the

1327
00:53:44,069 --> 00:53:42,480
director of all this they did a lot most

1328
00:53:45,430 --> 00:53:44,079
of the hard work

1329
00:53:47,910 --> 00:53:45,440
and i also have to thank matt our

1330
00:53:48,870 --> 00:53:47,920
funding agent from nasa's universal

1331
00:53:55,670 --> 00:53:48,880
learning

1332
00:53:57,750 --> 00:53:55,680
this is not an entertainment movie this

1333
00:53:59,670 --> 00:53:57,760
is a movie that's trying to

1334
00:54:01,670 --> 00:53:59,680
yes it's trying to be cinematic and show

1335
00:54:03,910 --> 00:54:01,680
you some really gorgeous stuff but it's

1336
00:54:06,230 --> 00:54:03,920
also trying to

1337
00:54:08,069 --> 00:54:06,240
teach you a story i don't want to say

1338
00:54:11,030 --> 00:54:08,079

teach i want to i'm going to present you

1339
00:54:12,950 --> 00:54:11,040
with a a story so that you gain some

1340
00:54:16,549 --> 00:54:12,960
knowledge while watching it

1341
00:54:19,030 --> 00:54:16,559
so you'll notice that it is not narrated

1342
00:54:21,430 --> 00:54:19,040
but instead it has the captions on

1343
00:54:22,790 --> 00:54:21,440
screen that you can read

1344
00:54:25,349 --> 00:54:22,800
and people have asked me well why don't

1345
00:54:27,030 --> 00:54:25,359
you just hire a narrator and do that

1346
00:54:30,069 --> 00:54:27,040
and so people don't have to read and i

1347
00:54:32,950 --> 00:54:30,079
say that well we are trying to

1348
00:54:35,109 --> 00:54:32,960
be and put people in a learning mode

1349
00:54:37,750 --> 00:54:35,119
and when you read those

1350
00:54:39,109 --> 00:54:37,760
that you read the text on screen

1351
00:54:40,870 --> 00:54:39,119
you have to start a concentrate you have

1352
00:54:42,710 --> 00:54:40,880
to put yourself into it a little bit

1353
00:54:45,109 --> 00:54:42,720
more than if you're just sitting back

1354
00:54:46,549 --> 00:54:45,119
and watching something on youtube or

1355
00:54:47,910 --> 00:54:46,559
whatever streaming service you're happy

1356
00:54:49,349 --> 00:54:47,920
to be watching

1357
00:54:51,030 --> 00:54:49,359
we're not trying to do entertainment

1358
00:54:54,710 --> 00:54:51,040
we're trying to do

1359
00:54:57,349 --> 00:54:54,720
um focused and focu

1360
00:54:59,430 --> 00:54:57,359
enjoyable and of some focused learning

1361
00:55:02,150 --> 00:54:59,440
all right so if you want to see this

1362
00:55:03,829 --> 00:55:02,160
movie again um you can of course find it

1363
00:55:05,109 --> 00:55:03,839

on our hubble space telescope channel on

1364
00:55:06,549 --> 00:55:05,119
youtube which

1365
00:55:09,190 --> 00:55:06,559
the same channel that you're watching

1366
00:55:11,990 --> 00:55:09,200
right now in order to watch this talk

1367
00:55:15,109 --> 00:55:12,000
alright it is a four and a half minute

1368
00:55:18,710 --> 00:55:15,119
it has a soundtrack um and the text is

1369
00:55:26,300 --> 00:55:18,720
on screen so everybody please enjoy our

1370
00:58:26,710 --> 00:56:03,590
[Music]

1371
00:58:26,720 --> 00:58:31,800
so

1372
00:59:59,030 --> 00:59:46,670
[Music]

1373
01:00:05,190 --> 01:00:02,549
i hope you enjoyed our presentation um

1374
01:00:08,390 --> 01:00:05,200
every time i see it it's like okay yeah

1375
01:00:09,270 --> 01:00:08,400
these guys did a fantastic job

1376
01:00:12,150 --> 01:00:09,280
but

1377
01:00:13,030 --> 01:00:12,160
there's still more to learn about this

1378
01:00:16,789 --> 01:00:13,040
okay

1379
01:00:19,510 --> 01:00:16,799
so um as part of universal learning

1380
01:00:22,630 --> 01:00:19,520
we also have a project that creates this

1381
01:00:25,270 --> 01:00:22,640
website called universe unplugged

1382
01:00:27,430 --> 01:00:25,280
and in addition to these these videos

1383
01:00:29,510 --> 01:00:27,440
being posted on our hubble site and our

1384
01:00:31,990 --> 01:00:29,520
hubble space telescope channel on

1385
01:00:34,549 --> 01:00:32,000
youtube they're also posted here on

1386
01:00:38,150 --> 01:00:34,559
universe unplugged but what universe

1387
01:00:40,630 --> 01:00:38,160
unplugged does is it provides a lot more

1388
01:00:41,430 --> 01:00:40,640

resources to these videos

1389
01:00:49,589 --> 01:00:41,440
so

1390
01:00:52,150 --> 01:00:49,599
these here from our view space project

1391
01:00:54,150 --> 01:00:52,160
also part of the universe of learning

1392
01:00:57,430 --> 01:00:54,160
and these resources here from the

1393
01:01:00,630 --> 01:00:57,440
astropix project yet another thing from

1394
01:01:03,510 --> 01:01:00,640
universal learning as well as stuff from

1395
01:01:06,549 --> 01:01:03,520
the uh from our hubblecite website

1396
01:01:08,630 --> 01:01:06,559
and the worldwide telescope so

1397
01:01:11,109 --> 01:01:08,640
lots more to explore if you're

1398
01:01:14,630 --> 01:01:11,119
interested in exploring more

1399
01:01:18,390 --> 01:01:14,640
you can also find on universe unplugged

1400
01:01:21,829 --> 01:01:18,400
accessible learning resources

1401
01:01:23,430 --> 01:01:21,839
robert hurt took our 3d model of the

1402
01:01:25,190 --> 01:01:23,440
homunculus

1403
01:01:28,150 --> 01:01:25,200
and worked it out

1404
01:01:29,510 --> 01:01:28,160
into a 3d printable object and here you

1405
01:01:32,870 --> 01:01:29,520
can see

1406
01:01:34,710 --> 01:01:32,880
the 3d print of our ada car model so you

1407
01:01:36,309 --> 01:01:34,720
have a tactile

1408
01:01:38,230 --> 01:01:36,319
touchable

1409
01:01:39,750 --> 01:01:38,240
thing that you can hold and examine it

1410
01:01:43,829 --> 01:01:39,760
and understand

1411
01:01:45,430 --> 01:01:43,839
um and uh kim arkand up at the center

1412
01:01:47,990 --> 01:01:45,440
for astrophysics

1413
01:01:50,150 --> 01:01:48,000

took our visualization and used it in

1414
01:01:53,990 --> 01:01:50,160
her sonification project

1415
01:01:55,910 --> 01:01:54,000
universe of sound and a link to that is

1416
01:01:58,710 --> 01:01:55,920
as i said available on the universe

1417
01:02:00,630 --> 01:01:58,720
unplugged website so through the

1418
01:02:03,029 --> 01:02:00,640
universe of learning we've got various

1419
01:02:05,829 --> 01:02:03,039
ways of exploring it we take our base

1420
01:02:07,910 --> 01:02:05,839
product of the edicar visualization and

1421
01:02:11,029 --> 01:02:07,920
use it in multiple ways

1422
01:02:13,750 --> 01:02:11,039
uh it also served as an impetus for this

1423
01:02:14,950 --> 01:02:13,760
year's nasa's astrophoto

1424
01:02:21,190 --> 01:02:14,960
challenges

1425
01:02:23,510 --> 01:02:21,200
that you can try your hand at processing

1426
01:02:25,990 --> 01:02:23,520
or capturing images

1427
01:02:28,950 --> 01:02:26,000
and the 2022 calendar challenges as you

1428
01:02:30,470 --> 01:02:28,960
can see here are adacar and the karina

1429
01:02:32,870 --> 01:02:30,480
nebula

1430
01:02:36,150 --> 01:02:32,880
there is a nasa data challenge

1431
01:02:39,270 --> 01:02:36,160
which provides data taken by several

1432
01:02:42,710 --> 01:02:39,280
nasus telescopes and and you can figure

1433
01:02:44,390 --> 01:02:42,720
out how you want to put together um the

1434
01:02:46,549 --> 01:02:44,400
the version of an image

1435
01:02:47,670 --> 01:02:46,559
or there is the micro observatory

1436
01:02:49,750 --> 01:02:47,680
challenge

1437
01:02:51,589 --> 01:02:49,760
where you get to actually observe using

1438
01:02:53,750 --> 01:02:51,599

a robotic telescope you don't know sorry

1439
01:02:55,510 --> 01:02:53,760
you don't get to go to the telescope

1440
01:02:57,910 --> 01:02:55,520
and sit on the mountain top and do it

1441
01:03:00,230 --> 01:02:57,920
but over the internet

1442
01:03:01,910 --> 01:03:00,240
you can use a robotic telescope to take

1443
01:03:06,630 --> 01:03:01,920
observations

1444
01:03:09,270 --> 01:03:06,640
process your own image

1445
01:03:11,990 --> 01:03:09,280
this nasa's astrophoto challenge just

1446
01:03:14,789 --> 01:03:12,000
opened yesterday

1447
01:03:18,950 --> 01:03:14,799
and is now open through the summer

1448
01:03:21,190 --> 01:03:18,960
submissions are due on july 31st

1449
01:03:23,750 --> 01:03:21,200
uh and finally

1450
01:03:28,150 --> 01:03:23,760
one of the things that is coming soon

1451
01:03:32,069 --> 01:03:28,160
actually in two weeks um is dome slash

1452
01:03:34,950 --> 01:03:32,079
vr version of our visualization

1453
01:03:38,069 --> 01:03:34,960
so uh i don't have a

1454
01:03:39,750 --> 01:03:38,079
dome here in my basement

1455
01:03:42,710 --> 01:03:39,760
i don't work at a planetarium i can't

1456
01:03:44,870 --> 01:03:42,720
use a dome so what i actually do is

1457
01:03:47,029 --> 01:03:44,880
here's a picture of me sitting in my

1458
01:03:49,029 --> 01:03:47,039
office pre-pandemic back when i was

1459
01:03:52,710 --> 01:03:49,039
still in my office

1460
01:03:55,589 --> 01:03:52,720
utilizing vr goggles to create a virtual

1461
01:03:58,150 --> 01:03:55,599
dome around me so i can spin around and

1462
01:04:01,430 --> 01:03:58,160
look and see what the visualization

1463
01:04:04,710 --> 01:04:01,440

looks like uh in a dome setting

1464
01:04:07,589 --> 01:04:04,720
that allows me to create a dome version

1465
01:04:09,990 --> 01:04:07,599
this is a frame from one of the dome

1466
01:04:11,829 --> 01:04:10,000
versions um that will debut at the

1467
01:04:14,470 --> 01:04:11,839
middle atlantic planetarium society

1468
01:04:16,870 --> 01:04:14,480
conference in mid-may basically two

1469
01:04:18,230 --> 01:04:16,880
weeks from when i'm giving this talk

1470
01:04:19,349 --> 01:04:18,240
all right

1471
01:04:22,789 --> 01:04:19,359
so

1472
01:04:26,390 --> 01:04:22,799
that is our exploration of edicarinae

1473
01:04:29,390 --> 01:04:26,400
and the homunculus nebula in 3d

1474
01:04:32,230 --> 01:04:29,400
you can see that we explore it in as

1475
01:04:34,870 --> 01:04:32,240
multi-wavelength glory we can produce

1476
01:04:36,230 --> 01:04:34,880
multi formats in terms of

1477
01:04:45,029 --> 01:04:36,240
the

1478
01:04:48,950 --> 01:04:45,039
like to say it's a multi-wavelength

1479
01:04:51,190 --> 01:04:48,960
multi-format multi-sensory experience of

1480
01:04:55,430 --> 01:04:51,200
one of this night sky's

1481
01:05:00,950 --> 01:04:55,440
coolest most interesting cosmic objects

1482
01:05:05,510 --> 01:05:02,470
all right

1483
01:05:07,510 --> 01:05:05,520
so i have finished my talk and at this

1484
01:05:09,589 --> 01:05:07,520
point i would usually take the host

1485
01:05:12,710 --> 01:05:09,599
privilege of asking the first question

1486
01:05:16,309 --> 01:05:12,720
but that would be kind of weird

1487
01:05:18,470 --> 01:05:16,319
so grant has jumped on very quickly uh

1488
01:05:20,470 --> 01:05:18,480

grant you've been monitoring the chat

1489
01:05:23,430 --> 01:05:20,480
do we have some questions from the chat

1490
01:05:26,390 --> 01:05:23,440
today we do we do we have a solid online

1491
01:05:28,150 --> 01:05:26,400
audience today um so to start off with

1492
01:05:30,470 --> 01:05:28,160
it is a question that we get often but

1493
01:05:32,470 --> 01:05:30,480
i'm going to have to ask you again

1494
01:05:36,069 --> 01:05:32,480
what is the difference between your

1495
01:05:37,910 --> 01:05:36,079
visualizations and an artist's rendition

1496
01:05:40,549 --> 01:05:37,920
ah all right so

1497
01:05:43,990 --> 01:05:40,559
our scientific visualizations are based

1498
01:05:46,630 --> 01:05:44,000
on scientific knowledge right um you can

1499
01:05:49,190 --> 01:05:46,640
see that we utilize the scientific model

1500
01:05:51,990 --> 01:05:49,200
created by stefan at all as the basis

1501
01:05:55,029 --> 01:05:52,000
for our homunculus model we use the data

1502
01:05:55,829 --> 01:05:55,039
from um hubble and from

1503
01:05:59,190 --> 01:05:55,839
uh

1504
01:06:02,390 --> 01:05:59,200
chandra as the basis for our

1505
01:06:04,630 --> 01:06:02,400
our 3d visualizations uh we are trying

1506
01:06:06,630 --> 01:06:04,640
to be scientifically as scientifically

1507
01:06:08,390 --> 01:06:06,640
accurate as reasonable for our cinematic

1508
01:06:10,309 --> 01:06:08,400
level of visualization

1509
01:06:12,230 --> 01:06:10,319
i will say however that we are not

1510
01:06:13,670 --> 01:06:12,240
trying to be perfectly scientifically

1511
01:06:16,069 --> 01:06:13,680
accurate

1512
01:06:18,470 --> 01:06:16,079
to do so would be well certainly

1513
01:06:20,390 --> 01:06:18,480

impossible for things like the uh

1514
01:06:22,390 --> 01:06:20,400
infrared

1515
01:06:24,230 --> 01:06:22,400
pull out where we had to have thousands

1516
01:06:26,549 --> 01:06:24,240
of stars and we could never figure out

1517
01:06:29,910 --> 01:06:26,559
all the distances on them

1518
01:06:33,510 --> 01:06:29,920
but the idea is to give you a good

1519
01:06:35,109 --> 01:06:33,520
mental model of the structures

1520
01:06:37,270 --> 01:06:35,119
in 3d

1521
01:06:40,630 --> 01:06:37,280
that you might see in these images so

1522
01:06:42,630 --> 01:06:40,640
you see a 2d flat image from nasa how do

1523
01:06:44,230 --> 01:06:42,640
you interpret that in 3d

1524
01:06:46,870 --> 01:06:44,240
one of the most important things i can

1525
01:06:48,710 --> 01:06:46,880
do for you is give you that mental model

1526
01:06:49,670 --> 01:06:48,720
with which you can then interpret that

1527
01:06:51,510 --> 01:06:49,680
image

1528
01:06:53,190 --> 01:06:51,520
and that's uh

1529
01:06:56,069 --> 01:06:53,200
not something you will find from an

1530
01:06:58,950 --> 01:06:56,079
animation uh animations are generally

1531
01:07:01,750 --> 01:06:58,960
drawn from the artist's head they don't

1532
01:07:04,150 --> 01:07:01,760
think they can use you know um

1533
01:07:06,230 --> 01:07:04,160
materials to inspire them but they're

1534
01:07:09,430 --> 01:07:06,240
not constrained by uh

1535
01:07:11,430 --> 01:07:09,440
trying to get the science ideas right um

1536
01:07:13,349 --> 01:07:11,440
and and and get the correct messages

1537
01:07:14,710 --> 01:07:13,359
across they're just trying to oftentimes

1538
01:07:16,470 --> 01:07:14,720

just trying to make something beautiful

1539
01:07:17,990 --> 01:07:16,480
or something spectacular or something

1540
01:07:19,109 --> 01:07:18,000
exciting

1541
01:07:22,470 --> 01:07:19,119
and so

1542
01:07:24,549 --> 01:07:22,480
this is a constrained by the science uh

1543
01:07:25,910 --> 01:07:24,559
for our visualizations

1544
01:07:27,750 --> 01:07:25,920
awesome thank you we actually have

1545
01:07:30,630 --> 01:07:27,760
someone in the chat who worked on it at

1546
01:07:32,710 --> 01:07:30,640
uh goddard's place space flight center

1547
01:07:35,109 --> 01:07:32,720
she says they created the model from the

1548
01:07:37,430 --> 01:07:35,119
molecular hydrogen emissions that were

1549
01:07:38,710 --> 01:07:37,440
extracted from eso and ex-shooter

1550
01:07:41,589 --> 01:07:38,720
observations

1551
01:07:45,750 --> 01:07:43,190
all right so

1552
01:07:47,589 --> 01:07:45,760
we'll move on to our next question here

1553
01:07:49,270 --> 01:07:47,599
um all right so when we were actually

1554
01:07:52,630 --> 01:07:49,280
talking about

1555
01:07:55,190 --> 01:07:52,640
uh adacarade itself uh you had the the

1556
01:07:59,109 --> 01:07:55,200
visualization up

1557
01:08:00,950 --> 01:07:59,119
is the equatorial plane of the nebula

1558
01:08:02,390 --> 01:08:00,960
also the orbital plane of the binary

1559
01:08:04,870 --> 01:08:02,400
system

1560
01:08:07,430 --> 01:08:04,880
that i do not know um and i'm not sure

1561
01:08:08,470 --> 01:08:07,440
anybody knows that okay i look to try

1562
01:08:10,870 --> 01:08:08,480
and see if

1563
01:08:13,589 --> 01:08:10,880

that that i could find a paper that said

1564
01:08:15,270 --> 01:08:13,599
definitively yes or no um i did not find

1565
01:08:16,390 --> 01:08:15,280
one um

1566
01:08:19,110 --> 01:08:16,400
however

1567
01:08:23,110 --> 01:08:19,120
um if there is this colliding wind

1568
01:08:25,430 --> 01:08:23,120
binary system and there is an axis um uh

1569
01:08:28,709 --> 01:08:25,440
you it's it would be a good

1570
01:08:30,390 --> 01:08:28,719
uh hypothesis that um the the plane of

1571
01:08:32,390 --> 01:08:30,400
the um

1572
01:08:35,030 --> 01:08:32,400
the plane of the orbit would be the same

1573
01:08:37,189 --> 01:08:35,040
as equatorial plane of the system

1574
01:08:40,149 --> 01:08:37,199
why did the material flow out into

1575
01:08:42,390 --> 01:08:40,159
opposite directions okay what is there

1576
01:08:44,229 --> 01:08:42,400
that creates that thing um i had

1577
01:08:46,870 --> 01:08:44,239
originally thought that there was some

1578
01:08:48,950 --> 01:08:46,880
dust disk or heavy heavy material that's

1579
01:08:50,070 --> 01:08:48,960
stopping it that's collimating the flow

1580
01:08:52,470 --> 01:08:50,080
out

1581
01:08:53,990 --> 01:08:52,480
and uh chris davidson said no no no

1582
01:08:56,309 --> 01:08:54,000
that's not what's happening

1583
01:08:59,669 --> 01:08:56,319
it actually did blow off into direction

1584
01:09:00,390 --> 01:08:59,679
it's like okay um i have a hard time

1585
01:09:04,470 --> 01:09:00,400
as

1586
01:09:06,470 --> 01:09:04,480
that would happen you've got to have

1587
01:09:10,709 --> 01:09:06,480
some reason for

1588
01:09:11,669 --> 01:09:10,719

the the the the bipolar symmetry

1589
01:09:13,030 --> 01:09:11,679
okay

1590
01:09:15,430 --> 01:09:13,040
thank you

1591
01:09:16,950 --> 01:09:15,440
um also would you give a little more

1592
01:09:19,990 --> 01:09:16,960
insight onto like

1593
01:09:21,749 --> 01:09:20,000
what types of programs you use or i know

1594
01:09:25,030 --> 01:09:21,759
we have a whole special about this to

1595
01:09:28,390 --> 01:09:25,040
this user frank and one of our

1596
01:09:30,229 --> 01:09:28,400
uh resident um artists actually did a

1597
01:09:31,910 --> 01:09:30,239
whole talk about this what the different

1598
01:09:34,149 --> 01:09:31,920
colors mean all of that i would highly

1599
01:09:36,309 --> 01:09:34,159
suggest you guys check out that public

1600
01:09:39,110 --> 01:09:36,319
talk but for the sake of this one for a

1601
01:09:41,349 --> 01:09:39,120
condensed answer

1602
01:09:42,950 --> 01:09:41,359
all right so in terms of the software we

1603
01:09:45,510 --> 01:09:42,960
use we use

1604
01:09:48,789 --> 01:09:45,520
anything that does the job okay

1605
01:09:50,709 --> 01:09:48,799
a lot of the time when i am taking the

1606
01:09:52,950 --> 01:09:50,719
raw scientific data and turning it into

1607
01:09:55,110 --> 01:09:52,960
data that i can use in a visualization

1608
01:09:57,189 --> 01:09:55,120
i'm writing perl code

1609
01:09:59,350 --> 01:09:57,199
perl scripts i'm writing c code i'm

1610
01:10:01,350 --> 01:09:59,360
writing fortran code i'm doing whatever

1611
01:10:03,830 --> 01:10:01,360
whatever coding i can i can greet to

1612
01:10:06,310 --> 01:10:03,840
take the the scientific data pull it

1613
01:10:07,590 --> 01:10:06,320

into things once we've got it into those

1614
01:10:10,790 --> 01:10:07,600
packages

1615
01:10:11,590 --> 01:10:10,800
we use standard 3d modeling programs and

1616
01:10:13,830 --> 01:10:11,600
i'm

1617
01:10:17,189 --> 01:10:13,840
actually not supposed to say which 3d

1618
01:10:19,110 --> 01:10:17,199
modeling packages we use because we're

1619
01:10:20,550 --> 01:10:19,120
nasa we're not supposed to

1620
01:10:22,070 --> 01:10:20,560
advertise

1621
01:10:23,990 --> 01:10:22,080
first different

1622
01:10:26,709 --> 01:10:24,000
for different

1623
01:10:28,950 --> 01:10:26,719
company for companies but i will say

1624
01:10:30,870 --> 01:10:28,960
it's the same 3d modeling programs that

1625
01:10:32,950 --> 01:10:30,880
hollywood uses for these blockbuster

1626
01:10:35,910 --> 01:10:32,960
films okay

1627
01:10:38,229 --> 01:10:35,920
hollywood has put tremendous money into

1628
01:10:41,750 --> 01:10:38,239
creating 3d modeling programs that do

1629
01:10:43,669 --> 01:10:41,760
amazing things and 90 of it we don't we

1630
01:10:45,430 --> 01:10:43,679
wouldn't use for science but

1631
01:10:47,510 --> 01:10:45,440
since they've created such great things

1632
01:10:50,070 --> 01:10:47,520
especially their camera choreography oh

1633
01:10:51,590 --> 01:10:50,080
my god i love the camera choreography

1634
01:10:54,709 --> 01:10:51,600
tools that they've written

1635
01:10:56,470 --> 01:10:54,719
we use that we also use your uh image

1636
01:10:57,669 --> 01:10:56,480
processing programs

1637
01:11:02,229 --> 01:10:57,679
that

1638
01:11:04,950 --> 01:11:02,239

change them we use the compositing

1639
01:11:07,430 --> 01:11:04,960
programs that also holly hollywood uses

1640
01:11:10,470 --> 01:11:07,440
um we've diversified into using lots of

1641
01:11:11,910 --> 01:11:10,480
different ones um and so as i said we

1642
01:11:13,189 --> 01:11:11,920
sort of will use whatever tool is

1643
01:11:15,590 --> 01:11:13,199
necessary

1644
01:11:18,149 --> 01:11:15,600
to get things and get things out

1645
01:11:20,149 --> 01:11:18,159
and we really could not have done this

1646
01:11:21,510 --> 01:11:20,159
if we weren't able to sponge off of

1647
01:11:23,189 --> 01:11:21,520
hollywood

1648
01:11:25,189 --> 01:11:23,199
and the investment that companies have

1649
01:11:27,590 --> 01:11:25,199
made to sell their products to hollywood

1650
01:11:29,270 --> 01:11:27,600
so that we can use you know a time a

1651
01:11:31,830 --> 01:11:29,280
small percentage of that stuff but you

1652
01:11:35,030 --> 01:11:31,840
know have really sophisticated tools uh

1653
01:11:36,390 --> 01:11:35,040
and use them for science

1654
01:11:40,149 --> 01:11:36,400
awesome

1655
01:11:42,390 --> 01:11:40,159
um all right so uh as far as ada carr

1656
01:11:44,470 --> 01:11:42,400
where do you see this going in terms of

1657
01:11:46,790 --> 01:11:44,480
scientific observation

1658
01:11:49,510 --> 01:11:46,800
what do you think would be the next

1659
01:11:51,590 --> 01:11:49,520
study done on it ah

1660
01:11:55,189 --> 01:11:51,600
well i would like to know where that

1661
01:11:57,350 --> 01:11:55,199
fast ejecta is okay can they design a

1662
01:12:01,110 --> 01:11:57,360
study in order to observe that fast

1663
01:12:02,550 --> 01:12:01,120

ejecta that's uh creating that um

1664
01:12:04,390 --> 01:12:02,560
that's creating the x-rays on the

1665
01:12:06,229 --> 01:12:04,400
outside um

1666
01:12:07,350 --> 01:12:06,239
that was the the one of the big

1667
01:12:11,430 --> 01:12:07,360
questions and

1668
01:12:13,750 --> 01:12:11,440
i've got partial answer there on that

1669
01:12:16,550 --> 01:12:13,760
most of the

1670
01:12:18,950 --> 01:12:16,560
main research that's being done on the

1671
01:12:21,189 --> 01:12:18,960
on a car right now is really down in the

1672
01:12:23,990 --> 01:12:21,199
binary system trying to understand the

1673
01:12:26,790 --> 01:12:24,000
energetics of what happens when it's at

1674
01:12:28,709 --> 01:12:26,800
uh periastron when it's at app astron

1675
01:12:30,709 --> 01:12:28,719
following the energetics of this trying

1676
01:12:31,830 --> 01:12:30,719
to figure out how the

1677
01:12:33,110 --> 01:12:31,840
um

1678
01:12:35,590 --> 01:12:33,120
how the great eruption could have

1679
01:12:36,470 --> 01:12:35,600
happened to produce this uh amazing

1680
01:12:38,630 --> 01:12:36,480
thing

1681
01:12:40,149 --> 01:12:38,640
uh amazing amount of energy uh

1682
01:12:42,790 --> 01:12:40,159
production violence so they're going to

1683
01:12:45,350 --> 01:12:42,800
continue doing that um i was talking

1684
01:12:46,470 --> 01:12:45,360
with one of the researchers last week um

1685
01:12:48,709 --> 01:12:46,480
he said he

1686
01:12:50,390 --> 01:12:48,719
he was like oh man you you should have

1687
01:12:51,750 --> 01:12:50,400
done this project you know a year from

1688
01:12:53,189 --> 01:12:51,760

now because we got some really good

1689
01:12:55,189 --> 01:12:53,199
papers coming out this summer that

1690
01:12:57,270 --> 01:12:55,199
you'll be able to use and really show

1691
01:12:59,110 --> 01:12:57,280
even more what's going on

1692
01:13:01,510 --> 01:12:59,120
um and so

1693
01:13:04,630 --> 01:13:01,520
i find that happens a lot that we we did

1694
01:13:06,420 --> 01:13:04,640
the uh we did the crab nebula right

1695
01:13:08,630 --> 01:13:06,430
you're saying there's a part two

1696
01:13:10,550 --> 01:13:08,640
[Laughter]

1697
01:13:12,149 --> 01:13:10,560
well i don't know in terms of what we

1698
01:13:14,790 --> 01:13:12,159
were doing we're doing we're doing the

1699
01:13:18,390 --> 01:13:14,800
big structures in 3d so that we can give

1700
01:13:20,149 --> 01:13:18,400
the public a feel of that um i think his

1701
01:13:22,149 --> 01:13:20,159
papers are going to be about the the

1702
01:13:24,310 --> 01:13:22,159
core energy that's going on in there and

1703
01:13:25,669 --> 01:13:24,320
we'll understand it a bit more but it's

1704
01:13:28,310 --> 01:13:25,679
not really going to change the 3d

1705
01:13:30,790 --> 01:13:28,320
structure that we visualized in this

1706
01:13:32,630 --> 01:13:30,800
one and you know

1707
01:13:34,709 --> 01:13:32,640
with all apologies to the researchers

1708
01:13:36,790 --> 01:13:34,719
who do this the public

1709
01:13:38,870 --> 01:13:36,800
doesn't truly care

1710
01:13:39,990 --> 01:13:38,880
all about all these tiny details or at

1711
01:13:41,510 --> 01:13:40,000
least it's very hard to get them

1712
01:13:43,270 --> 01:13:41,520
interested in all these things our

1713
01:13:45,430 --> 01:13:43,280

audience here yeah we can get we can go

1714
01:13:47,430 --> 01:13:45,440
into a lot more detail but there was

1715
01:13:49,110 --> 01:13:47,440
only so much depth we could go into a

1716
01:13:51,350 --> 01:13:49,120
four and a half minute one when you're

1717
01:13:53,910 --> 01:13:51,360
making it for the uh for the general

1718
01:13:57,110 --> 01:13:53,920
public um there's uh all sorts of cool

1719
01:13:58,709 --> 01:13:57,120
scientific research details um and we

1720
01:14:00,470 --> 01:13:58,719
have to find the right form uh upon

1721
01:14:03,189 --> 01:14:00,480
which to find that audience that's

1722
01:14:05,270 --> 01:14:03,199
interested in those

1723
01:14:07,910 --> 01:14:05,280
all right and kind of piggybacking off

1724
01:14:10,070 --> 01:14:07,920
that do we have any sort of approximate

1725
01:14:12,070 --> 01:14:10,080
size or distance from the nebula's

1726
01:14:13,189 --> 01:14:12,080
center to outer layers do we do we have

1727
01:14:15,830 --> 01:14:13,199
any idea

1728
01:14:18,470 --> 01:14:15,840
okay yeah so i sort of meant i meant to

1729
01:14:21,430 --> 01:14:18,480
mention this um i think the um my my

1730
01:14:24,550 --> 01:14:21,440
recollection is the size of each lobe

1731
01:14:25,590 --> 01:14:24,560
is about four tenths of a light year

1732
01:14:28,229 --> 01:14:25,600
okay

1733
01:14:30,790 --> 01:14:28,239
um that the stuff's been expanding it

1734
01:14:33,590 --> 01:14:30,800
you know like 600 kilometers per second

1735
01:14:36,790 --> 01:14:33,600
for 200 years you do the math on that um

1736
01:14:39,910 --> 01:14:36,800
you get about 400 uh for four tenths of

1737
01:14:41,910 --> 01:14:39,920
a light year uh in diameter for that for

1738
01:14:43,830 --> 01:14:41,920

each of those so approximately a little

1739
01:14:46,630 --> 01:14:43,840
less than a light year across the the

1740
01:14:48,390 --> 01:14:46,640
entire ada car um and if one of the

1741
01:14:50,229 --> 01:14:48,400
researchers is watching this please

1742
01:14:53,189 --> 01:14:50,239
correct me in the comments if i'm if i'm

1743
01:14:55,990 --> 01:14:53,199
wrong on that uh myron teodoro the

1744
01:14:56,790 --> 01:14:56,000
person who worked on it says uh 21 000 a

1745
01:15:03,510 --> 01:14:56,800
u

1746
01:15:04,790 --> 01:15:03,520
an expert in the chat this is great

1747
01:15:07,990 --> 01:15:04,800
thank you

1748
01:15:10,390 --> 01:15:08,000
all right so um

1749
01:15:12,390 --> 01:15:10,400
are there studies going on as to what

1750
01:15:14,470 --> 01:15:12,400
stopped ada carr from going all the way

1751
01:15:16,390 --> 01:15:14,480
to supernova

1752
01:15:18,390 --> 01:15:16,400
um if you're trying to figure out what

1753
01:15:20,390 --> 01:15:18,400
caused it to go with this great eruption

1754
01:15:23,590 --> 01:15:20,400
i think you you got to figure out some

1755
01:15:25,189 --> 01:15:23,600
way that uh yeah why does it stop i mean

1756
01:15:28,229 --> 01:15:25,199
if it was a

1757
01:15:29,030 --> 01:15:28,239
small-scale supernova right um

1758
01:15:31,830 --> 01:15:29,040
well

1759
01:15:33,350 --> 01:15:31,840
why didn't it go all the way um was it

1760
01:15:33,990 --> 01:15:33,360
their insta

1761
01:15:35,510 --> 01:15:34,000
and

1762
01:15:37,510 --> 01:15:35,520
you know

1763
01:15:40,709 --> 01:15:37,520

my understanding is that ada car a is

1764
01:15:42,790 --> 01:15:40,719
only a million years old okay and yeah

1765
01:15:43,830 --> 01:15:42,800
these massive stars burn through their

1766
01:15:45,990 --> 01:15:43,840
uh

1767
01:15:49,110 --> 01:15:46,000
undergo nuclear fusion very very fast

1768
01:15:51,350 --> 01:15:49,120
and they they uh go through their they

1769
01:15:54,070 --> 01:15:51,360
fuse hydrogen at a really really rapid

1770
01:15:55,669 --> 01:15:54,080
pace um but you're not gonna get a

1771
01:15:57,510 --> 01:15:55,679
supernova while you're still in the

1772
01:15:58,550 --> 01:15:57,520
hydrogen burning phase and that was my

1773
01:16:00,310 --> 01:15:58,560
understanding was it was still the

1774
01:16:03,669 --> 01:16:00,320
hydrogen burning phase so

1775
01:16:07,510 --> 01:16:03,679
i didn't see how you could get a small

1776
01:16:10,229 --> 01:16:07,520
scale supernova type thing um so that

1777
01:16:11,830 --> 01:16:10,239
was a little confusing to me um but you

1778
01:16:13,430 --> 01:16:11,840
know i

1779
01:16:15,910 --> 01:16:13,440
i know that the researchers will

1780
01:16:18,830 --> 01:16:15,920
continue to look look for that um so if

1781
01:16:21,830 --> 01:16:18,840
you're gonna get a runaway uh a

1782
01:16:24,149 --> 01:16:21,840
fusion uh or whatever whatever processes

1783
01:16:26,550 --> 01:16:24,159
that runs away it has to be a temporary

1784
01:16:29,189 --> 01:16:26,560
runaway but then it has to uh

1785
01:16:30,070 --> 01:16:29,199
die out and and and come back

1786
01:16:31,910 --> 01:16:30,080
um

1787
01:16:34,709 --> 01:16:31,920
they say that you know

1788
01:16:36,790 --> 01:16:34,719

based upon internal structure arguments

1789
01:16:40,870 --> 01:16:36,800
that it should have recovered after

1790
01:16:42,390 --> 01:16:40,880
about 40 years but here we are only 180

1791
01:16:43,990 --> 01:16:42,400
years later and it has still hasn't

1792
01:16:45,350 --> 01:16:44,000
fully recovered so

1793
01:16:48,630 --> 01:16:45,360
i think that

1794
01:16:50,390 --> 01:16:48,640
sort of it speaks to how we only know so

1795
01:16:51,990 --> 01:16:50,400
much about it and we're still working on

1796
01:16:55,590 --> 01:16:52,000
it

1797
01:16:58,070 --> 01:16:55,600
all right and uh the chat i believe you

1798
01:17:02,709 --> 01:16:58,080
have answered all of their questions

1799
01:17:07,669 --> 01:17:04,870
all right then well

1800
01:17:10,709 --> 01:17:07,679
thank you all for uh listening to today

1801
01:17:13,830 --> 01:17:10,719
uh we will be back in june cameron

1802
01:17:16,630 --> 01:17:13,840
hummels will talk about about the

1803
01:17:18,550 --> 01:17:16,640
formation and evolution of galaxies