PUBLIC LECTURE SERIES

# Red and Brown Dwarfs: Understanding our Smallest and Closest (sub)Stellar Neighbors

---

Featuring Guest Speaker:

**Serge Dieterich**

1
00:00:04,490 --> 00:00:01,389
and welcome to the Space Telescope

2
00:00:06,680 --> 00:00:04,500
public lecture series I'm your host dr.

3
00:00:09,230 --> 00:00:06,690
Frank summers from the office of public

4
00:00:12,020 --> 00:00:09,240
outreach and when you came in tonight

5
00:00:13,339 --> 00:00:12,030
hopefully you got a new lithograph this

6
00:00:15,829 --> 00:00:13,349
is the first time we've given out this

7
00:00:18,740 --> 00:00:15,839
lithograph it's brand-new this year it

8
00:00:20,140 --> 00:00:18,750
is of the Triangulum galaxy also known

9
00:00:23,300 --> 00:00:20,150
as m33

10
00:00:25,700 --> 00:00:23,310
also known as the third largest galaxies

11
00:00:28,130 --> 00:00:25,710
in our local group our local group has

12
00:00:30,500 --> 00:00:28,140
the Milky Way and Andromeda has two

13
00:00:32,720 --> 00:00:30,510

large size galaxies m33 is a

14
00:00:34,220 --> 00:00:32,730
medium-sized galaxy okay and then

15
00:00:36,380 --> 00:00:34,230
everything else in the local group is

16
00:00:39,080 --> 00:00:36,390
just flotsam and jetsam dwarf galaxies

17
00:00:42,979 --> 00:00:39,090
so this is the third important galaxies

18
00:00:45,950 --> 00:00:42,989
in our local group this image I gotta

19
00:00:48,619 --> 00:00:45,960
say is so incredible you can't tell from

20
00:00:52,069 --> 00:00:48,629
the lower graph because it's a really

21
00:00:54,650 --> 00:00:52,079
really detailed map of the stars in the

22
00:00:56,959 --> 00:00:54,660
Triangulum galaxy okay we did the phat

23
00:00:59,299 --> 00:00:56,969
survey which would incredibly deep into

24
00:01:01,250 --> 00:00:59,309
the Andromeda galaxy this is the same

25
00:01:03,369 --> 00:01:01,260
similar survey to go really deep and

26
00:01:06,590 --> 00:01:03,379
look at the stellar populations in the

27
00:01:08,600 --> 00:01:06,600
Triangulum galaxy so flip over on the

28
00:01:10,820 --> 00:01:08,610
back and we'll describe some of the

29
00:01:13,130 --> 00:01:10,830
things about what we can see in this

30
00:01:14,480 --> 00:01:13,140
amazingly detailed image that are so

31
00:01:17,929 --> 00:01:14,490
many more pixels that we could possibly

32
00:01:21,200 --> 00:01:17,939
put onto a lithograph actually we blow

33
00:01:23,600 --> 00:01:21,210
this up to like you know 1215 feet wide

34
00:01:25,640 --> 00:01:23,610
in order to see all the pixels okay

35
00:01:28,130 --> 00:01:25,650
that's how detailed this image really is

36
00:01:31,609 --> 00:01:28,140
you can go online and get all the pixels

37
00:01:33,440 --> 00:01:31,619
if you would like oh yes another

38
00:01:35,749 --> 00:01:33,450

reminder to silence your electronics

39
00:01:38,780 --> 00:01:35,759
making sure it's the both the phone the

40
00:01:41,359 --> 00:01:38,790
text and the camera clicks okay all

41
00:01:43,490 --> 00:01:41,369
right tonight red and brown dwarfs

42
00:01:45,109 --> 00:01:43,500
understanding our smallest and closest

43
00:01:48,590 --> 00:01:45,119
substellar neighbors I've been looking

44
00:01:49,670 --> 00:01:48,600
forward to this talk because these are

45
00:01:51,740 --> 00:01:49,680
the these are the guys that really

46
00:01:53,539 --> 00:01:51,750
matter okay all the big bright stars to

47
00:01:54,920 --> 00:01:53,549
get all the attention I think these are

48
00:01:55,340 --> 00:01:54,930
the stuff that wrote that that really

49
00:01:57,499 --> 00:01:55,350
matter

50
00:02:01,940 --> 00:01:57,509
Serg Diedrich we'll talk about that

51
00:02:04,520 --> 00:02:01,950
upcoming in January we have the double-a

52
00:02:07,160 --> 00:02:04,530
s meeting the first week of January and

53
00:02:08,990 --> 00:02:07,170
we have of course you know nears so we

54
00:02:13,010 --> 00:02:09,000
are not going until the second Tuesday

55
00:02:14,180 --> 00:02:13,020
January 14th okay January 14th second

56
00:02:16,699 --> 00:02:14,190
Tuesday

57
00:02:22,009 --> 00:02:16,709
nimisha Kumari will be talking Cloudy

58
00:02:24,890 --> 00:02:22,019
with a Chance of stars so this is just

59
00:02:25,880 --> 00:02:24,900
the general life of an astronomer who's

60
00:02:28,220 --> 00:02:25,890
observing right

61
00:02:29,690 --> 00:02:28,230
it's Cloudy with a Chance of stars I'm

62
00:02:31,180 --> 00:02:29,700
not exactly sure what she's talking

63
00:02:34,330 --> 00:02:31,190

about she hasn't given me an abstract

64
00:02:37,729 --> 00:02:34,340
but it sounds wonderful to me

65
00:02:42,680 --> 00:02:37,739
February 4th is to be announced I'll

66
00:02:44,839 --> 00:02:42,690
have that done by January and in March

67
00:02:48,380 --> 00:02:44,849
we have Nestor Espinosa talking about

68
00:02:51,410 --> 00:02:48,390
exoplanets a search for new worlds now

69
00:02:54,470 --> 00:02:51,420
for January February and March you must

70
00:02:56,630 --> 00:02:54,480
know that those coming in live the

71
00:02:59,349 --> 00:02:56,640
building will be under construction the

72
00:03:01,399 --> 00:02:59,359
lobby is going to undergo a redesign ok

73
00:03:02,930 --> 00:03:01,409
most of the building will be all just

74
00:03:06,979 --> 00:03:02,940
normal it's just the lobby is going to

75
00:03:09,680 --> 00:03:06,989
have a total total redesign strip it

76
00:03:11,899 --> 00:03:09,690
down build it back up ok which means

77
00:03:14,660 --> 00:03:11,909
that you probably won't be able to walk

78
00:03:16,430 --> 00:03:14,670
through the lobby to get into this into

79
00:03:18,379 --> 00:03:16,440
the thing there will probably be an

80
00:03:22,490 --> 00:03:18,389
alternate entrance there will be signs

81
00:03:24,379 --> 00:03:22,500
posted ok so next month February March

82
00:03:27,050 --> 00:03:24,389
look for the signs to see where you're

83
00:03:30,710 --> 00:03:27,060
supposed to enter ok if you need

84
00:03:33,500 --> 00:03:30,720
wheelchair access let us know because

85
00:03:35,690 --> 00:03:33,510
there this is the wheelchair ramp to get

86
00:03:38,629 --> 00:03:35,700
into here we can they said they can set

87
00:03:40,369 --> 00:03:38,639
it up and make sure it works but if you

88
00:03:44,569 --> 00:03:40,379

let us know in advance that will help us

89
00:03:46,879 --> 00:03:44,579
prepare for that ok and alright our

90
00:03:50,270 --> 00:03:46,889
website for the upcoming lectures and

91
00:03:53,960 --> 00:03:50,280
other things is STScI dot edu slash

92
00:03:56,869 --> 00:03:53,970
public - lectures easy for me to

93
00:04:00,379 --> 00:03:56,879
remember because some of the times we've

94
00:04:02,300 --> 00:04:00,389
had much much longer URLs here so we

95
00:04:05,390 --> 00:04:02,310
have lists to our webcast both on

96
00:04:06,920 --> 00:04:05,400
youtube let's see I got my spotlight

97
00:04:09,199 --> 00:04:06,930
remote here there we go

98
00:04:11,689 --> 00:04:09,209
both of our YouTube playlists and our

99
00:04:15,740 --> 00:04:11,699
webcast archives we have been doing

100
00:04:18,110 --> 00:04:15,750
webcasting since 2005 so that's 14 years

101
00:04:21,289 --> 00:04:18,120
of astronomical goodness for you to

102
00:04:24,649 --> 00:04:21,299
explore people like to binge watch

103
00:04:27,200 --> 00:04:24,659
hey let's binge watch astronomy if you

104
00:04:29,480 --> 00:04:27,210
would like notices about things

105
00:04:31,340 --> 00:04:29,490
we have our lecture announcements you

106
00:04:33,560 --> 00:04:31,350
can enter your email address here hit

107
00:04:35,750 --> 00:04:33,570
that button subscribe and you will get

108
00:04:37,939 --> 00:04:35,760
once a month or twice a month emails

109
00:04:40,250 --> 00:04:37,949
about what's coming up on our lecture

110
00:04:43,400 --> 00:04:40,260
series we also have lists of the

111
00:04:47,210 --> 00:04:43,410
upcoming lectures and for each lecture

112
00:04:50,270 --> 00:04:47,220
we have the details of it with the links

113
00:04:56,540 --> 00:04:50,280

to the STScI webcast up here and the

114
00:04:58,010 --> 00:04:56,550
YouTube webcast down here okay for email

115
00:04:59,689 --> 00:04:58,020
I talked about the announcements it's

116
00:05:01,760 --> 00:04:59,699
easiest to sign up the website but there

117
00:05:03,469 --> 00:05:01,770
are always people who don't want to sign

118
00:05:05,689 --> 00:05:03,479
up at the website and want to hand me a

119
00:05:08,360 --> 00:05:05,699
piece of paper that's fine as well I can

120
00:05:09,740 --> 00:05:08,370
handle paper if you have comments or

121
00:05:13,370 --> 00:05:09,750
questions you can send them to public

122
00:05:15,890 --> 00:05:13,380
lecture at sdsu dot edu if you would

123
00:05:17,930 --> 00:05:15,900
like our follow us on social media we're

124
00:05:21,110 --> 00:05:17,940
on Facebook and Twitter and YouTube and

125
00:05:24,500 --> 00:05:21,120
Instagram I myself am on Facebook and

126
00:05:26,360 --> 00:05:24,510
Twitter every now and then please do

127
00:05:27,950 --> 00:05:26,370
your social media thing as you as you

128
00:05:30,500 --> 00:05:27,960
like

129
00:05:34,040 --> 00:05:30,510
there will be no observatory after the

130
00:05:35,870 --> 00:05:34,050
lecture tonight the club they prediction

131
00:05:38,690 --> 00:05:35,880
was for a very cloudy weather so they

132
00:05:40,760 --> 00:05:38,700
cancelled it however as I always I note

133
00:05:43,460 --> 00:05:40,770
that there are open houses on Friday

134
00:05:45,409 --> 00:05:43,470
evenings on the Maryland Space Grant

135
00:05:47,180 --> 00:05:45,419
consortium website right here the

136
00:05:49,700 --> 00:05:47,190
observatory of status every Friday

137
00:05:51,500 --> 00:05:49,710
evening by 5:00 or 6:00 p.m. it's

138
00:05:53,810 --> 00:05:51,510

updated as to whether they will be open

139
00:05:55,520 --> 00:05:53,820
on Fridays so you can come and go up

140
00:05:58,730 --> 00:05:55,530
there and enjoy the observatories the

141
00:06:00,500 --> 00:05:58,740
nights that they are open all right so

142
00:06:06,879 --> 00:06:00,510
now our news from the universe for

143
00:06:12,140 --> 00:06:06,889
December 2019 first a Borissov update

144
00:06:14,060 --> 00:06:12,150
it's still fuzzy all right so what is

145
00:06:17,480 --> 00:06:14,070
Boris off some of you may not remember

146
00:06:19,070 --> 00:06:17,490
it is the second interstellar object

147
00:06:21,080 --> 00:06:19,080
that we have seen come through the solar

148
00:06:24,620 --> 00:06:21,090
system or that we have identified coming

149
00:06:27,800 --> 00:06:24,630
through the solar system and you can see

150
00:06:32,150 --> 00:06:27,810
here that it is was originally called C

151
00:06:34,219 --> 00:06:32,160
2019 q4 Borissov all right but it is now

152
00:06:38,630 --> 00:06:34,229
officially designated down here in the

153
00:06:40,820 --> 00:06:38,640
corner as 2i 2019 cube Borissov they C

154
00:06:43,220 --> 00:06:40,830
was a provisional designation the two

155
00:06:46,040 --> 00:06:43,230
I says it's the second interstellar

156
00:06:47,960 --> 00:06:46,050
object here you can see its path coming

157
00:06:50,540 --> 00:06:47,970
down through the plane of the solar

158
00:06:53,810 --> 00:06:50,550
system and shooting past it's moving at

159
00:06:56,690 --> 00:06:53,820
a tremendous speed so fast that the

160
00:07:00,050 --> 00:06:56,700
Sun's gravity cannot hold on to it okay

161
00:07:02,060 --> 00:07:00,060
it's moving at least twice as fast and

162
00:07:04,700 --> 00:07:02,070
so it has escape velocity from the solar

163
00:07:06,560 --> 00:07:04,710

system so this is a one-and-done comes

164
00:07:08,960 --> 00:07:06,570
through the solar system goodbye it's

165
00:07:11,200 --> 00:07:08,970
just a zooming past all right it shows

166
00:07:13,910 --> 00:07:11,210
us that things from interstellar space

167
00:07:16,520 --> 00:07:13,920
do come through our solar system all

168
00:07:19,100 --> 00:07:16,530
right and last month I showed you the

169
00:07:22,640 --> 00:07:19,110
picture of that Hubble god of Borissov

170
00:07:25,250 --> 00:07:22,650
on October 12th and I said well you know

171
00:07:28,280 --> 00:07:25,260
this is a very clear picture of a fuzzy

172
00:07:31,130 --> 00:07:28,290
object all right that was Hubble last

173
00:07:34,630 --> 00:07:31,140
month this month we go to a picture from

174
00:07:37,310 --> 00:07:34,640
the Keck telescope and it's still fuzzy

175
00:07:38,960 --> 00:07:37,320
now Keck of course is a ground-based

176
00:07:41,390 --> 00:07:38,970
telescope although it's a 10 meter

177
00:07:43,460 --> 00:07:41,400
telescope and can get has greater light

178
00:07:45,320 --> 00:07:43,470
gathering power than Hubble it is still

179
00:07:48,500 --> 00:07:45,330
of course on the ground and it doesn't

180
00:07:49,790 --> 00:07:48,510
have as clear resolution but one of the

181
00:07:53,270 --> 00:07:49,800
things they sense they have a greater

182
00:07:55,460 --> 00:07:53,280
light gathering power it can get a lot

183
00:07:58,940 --> 00:07:55,470
more of the tail and so they also

184
00:08:04,220 --> 00:07:58,950
produce this image showing the earth to

185
00:08:06,610 --> 00:08:04,230
scale yeah that tail is really really

186
00:08:08,720 --> 00:08:06,620
really long the tail of this comet is

187
00:08:11,960 --> 00:08:08,730
approximately a hundred thousand

188
00:08:14,420 --> 00:08:11,970

kilometers long but they estimate that

189
00:08:16,790 --> 00:08:14,430
the comet nucleus itself the ice ball

190
00:08:20,230 --> 00:08:16,800
that's actually spewing off all this gas

191
00:08:23,390 --> 00:08:20,240
and dust is only about a kilometer okay

192
00:08:26,690 --> 00:08:23,400
so the tail is a hundred thousand

193
00:08:29,120 --> 00:08:26,700
kilometers the ice ball is about one

194
00:08:31,640 --> 00:08:29,130
kilometer we're never gonna see that

195
00:08:34,070 --> 00:08:31,650
okay it's always gonna be a fuzzy thing

196
00:08:35,630 --> 00:08:34,080
okay unless you fly up to it

197
00:08:38,510 --> 00:08:35,640
you're not gonna be able to see that

198
00:08:40,250 --> 00:08:38,520
small little ice ball in there so all of

199
00:08:42,800 --> 00:08:40,260
it will be that way

200
00:08:44,980 --> 00:08:42,810
all right so the coming attractions for

201
00:08:48,830 --> 00:08:44,990
this this weekend

202
00:08:50,810 --> 00:08:48,840
it hits perihelion five days from now it

203
00:08:53,950 --> 00:08:50,820
will be 300 million kilometers from the

204
00:08:56,230 --> 00:08:53,960
Sun perigee is on December 28th

205
00:08:59,380 --> 00:08:56,240
it'll be 290 million kilometers from

206
00:09:02,590 --> 00:08:59,390
Earth so it never gets really close to

207
00:09:04,180 --> 00:09:02,600
any any either the Sun or or earth or

208
00:09:06,519 --> 00:09:04,190
actually any planet from that for that

209
00:09:08,980 --> 00:09:06,529
matter but it will be observable through

210
00:09:11,290 --> 00:09:08,990
late 2020 and when we skip this studies

211
00:09:13,329 --> 00:09:11,300
and look at them and we can might be

212
00:09:15,370 --> 00:09:13,339
able to tell its size shade composition

213
00:09:17,110 --> 00:09:15,380

perhaps its rotation speed and other

214
00:09:19,990 --> 00:09:17,120
things about it so we look forward to

215
00:09:21,699 --> 00:09:20,000
finding more about it but you know the

216
00:09:23,199 --> 00:09:21,709
next couple weeks might be really

217
00:09:25,720 --> 00:09:23,209
interesting because that's when it will

218
00:09:28,840 --> 00:09:25,730
be closer to the Sun the gases will be

219
00:09:30,970 --> 00:09:28,850
evaporating the most right now the word

220
00:09:34,210 --> 00:09:30,980
is it looks pretty much like any other

221
00:09:36,670 --> 00:09:34,220
comment it's hardly distinguishable from

222
00:09:37,120 --> 00:09:36,680
a normal solar system comet that's what

223
00:09:39,519 --> 00:09:37,130
I've heard

224
00:09:43,570 --> 00:09:39,529
have you heard anything else surged now

225
00:09:47,250 --> 00:09:43,580
yeah yeah so I don't know it's

226
00:09:51,460 --> 00:09:47,260
interstellar it seems to be so far

227
00:09:55,470 --> 00:09:51,470
pretty pretty normal okay alright our

228
00:09:58,630 --> 00:09:55,480
second story Raiders of the lenss darks

229
00:10:01,710 --> 00:09:58,640
yes I have no shame in the puns I will

230
00:10:04,420 --> 00:10:01,720
try and pull out okay alright so

231
00:10:06,370 --> 00:10:04,430
galaxies galaxies come in these giant

232
00:10:08,470 --> 00:10:06,380
clusters this is the Hercules cluster

233
00:10:10,840 --> 00:10:08,480
consisting of about a hundred two

234
00:10:13,510 --> 00:10:10,850
hundred galaxies these galaxies can pile

235
00:10:16,150 --> 00:10:13,520
together not just in tens and hundreds

236
00:10:19,480 --> 00:10:16,160
but even in the thousands and when you

237
00:10:21,720 --> 00:10:19,490
get a lot of galaxies together they pull

238
00:10:24,040 --> 00:10:21,730

together and they have a tremendous mass

239
00:10:25,690 --> 00:10:24,050
now for those of you who took your

240
00:10:30,970 --> 00:10:25,700
general relativity class in elementary

241
00:10:33,790 --> 00:10:30,980
school mass warps space okay you put a

242
00:10:35,949 --> 00:10:33,800
ton of mass together it warps the space

243
00:10:40,060 --> 00:10:35,959
and then the light traveling through

244
00:10:42,340 --> 00:10:40,070
warped space changes okay alright and we

245
00:10:44,880 --> 00:10:42,350
see that in the most massive galaxy

246
00:10:48,640 --> 00:10:44,890
clusters so here for example is a bell

247
00:10:51,340 --> 00:10:48,650
s106 three and there's so much mass in

248
00:10:55,900 --> 00:10:51,350
this galaxy cluster the space is really

249
00:11:00,040 --> 00:10:55,910
warped and then you can see these

250
00:11:02,140 --> 00:11:00,050
streaks here alright and those don't

251
00:11:04,360 --> 00:11:02,150
look like normal galaxies well they

252
00:11:06,940 --> 00:11:04,370
aren't no well actually they are normal

253
00:11:07,720 --> 00:11:06,950
galaxies but they said that the light

254
00:11:10,780 --> 00:11:07,730
has been

255
00:11:12,939 --> 00:11:10,790
due to gravitational lensing so normal

256
00:11:15,790 --> 00:11:12,949
galaxies like comes through this warp

257
00:11:18,180 --> 00:11:15,800
space it comes out as this streak

258
00:11:19,930 --> 00:11:18,190
we call these gravitationally lensed

259
00:11:22,780 --> 00:11:19,940
arcs okay

260
00:11:27,160 --> 00:11:22,790
hence the Raiders of the lens arcs all

261
00:11:29,290 --> 00:11:27,170
right there we go so these are lens arcs

262
00:11:31,240 --> 00:11:29,300
and these lens start can have some

263
00:11:34,360 --> 00:11:31,250

really interesting configurations for

264
00:11:36,610 --> 00:11:34,370
example here is a Bell 370 a very

265
00:11:39,550 --> 00:11:36,620
massive galaxy cluster and you can look

266
00:11:41,530 --> 00:11:39,560
over here on the right side and see this

267
00:11:43,689 --> 00:11:41,540
very interesting arc over here let me

268
00:11:46,660 --> 00:11:43,699
blow it up for you this has been

269
00:11:49,449 --> 00:11:46,670
nicknamed the dragon as you might tell

270
00:11:51,460 --> 00:11:49,459
by this by the shape of it you can see

271
00:11:54,910 --> 00:11:51,470
that it's a very long and sinewy type

272
00:11:58,900 --> 00:11:54,920
shape but what it really is is actually

273
00:12:01,120 --> 00:11:58,910
multiple images of the same galaxy so

274
00:12:03,879 --> 00:12:01,130
for example down the bottom here you can

275
00:12:05,319 --> 00:12:03,889
see what looks like a galaxy and then

276
00:12:07,750 --> 00:12:05,329
you can sort of see the same sort of

277
00:12:09,220 --> 00:12:07,760
structure and colors up here and the

278
00:12:11,590 --> 00:12:09,230
same sort of structures and colors up

279
00:12:13,689 --> 00:12:11,600
here I'm told that there may be like

280
00:12:17,230 --> 00:12:13,699
four different images of the same galaxy

281
00:12:19,420 --> 00:12:17,240
in this one arc which is kind of cool

282
00:12:23,199 --> 00:12:19,430
all right that you know the

283
00:12:24,970 --> 00:12:23,209
gravitational disturbance the warping of

284
00:12:27,100 --> 00:12:24,980
space so much is that this flow light

285
00:12:30,639 --> 00:12:27,110
from one galaxy passes four different

286
00:12:35,920 --> 00:12:30,649
ways through the the warp space around

287
00:12:38,350 --> 00:12:35,930
the cluster but that's not all so if you

288
00:12:39,819 --> 00:12:38,360

go after it you can really get something

289
00:12:42,699 --> 00:12:39,829
really cool and this is what we had a

290
00:12:49,660 --> 00:12:42,709
press release on last last month galaxy

291
00:12:51,430 --> 00:12:49,670
cluster psz 1g 3:1 1.65 - 18.4 8 won't

292
00:12:54,939 --> 00:12:51,440
just call it Betty okay so galaxy

293
00:12:58,900 --> 00:12:54,949
cluster Betty has a really cool feature

294
00:13:00,879 --> 00:12:58,910
in it that it has these interesting arcs

295
00:13:03,460 --> 00:13:00,889
on there are four of them and they're

296
00:13:07,809 --> 00:13:03,470
called the sunburst arcs okay and these

297
00:13:10,360 --> 00:13:07,819
sunburst arcs contain let's blow up two

298
00:13:13,949 --> 00:13:10,370
of them here right you look along those

299
00:13:17,500 --> 00:13:13,959
sunburst arcs there are more than twelve

300
00:13:21,100 --> 00:13:17,510
images of the same galaxies across these

301
00:13:24,220 --> 00:13:21,110
four arcs all right now the cluster

302
00:13:26,770 --> 00:13:24,230
cluster Betty up is about five billion

303
00:13:29,290 --> 00:13:26,780
light-years away the galaxy that's being

304
00:13:32,200 --> 00:13:29,300
lenss is about eleven billion light

305
00:13:33,940 --> 00:13:32,210
years away and at that distance for the

306
00:13:36,430 --> 00:13:33,950
brightness that it probably is

307
00:13:39,850 --> 00:13:36,440
it should not be observable by Hubble

308
00:13:41,230 --> 00:13:39,860
you can't see this galaxy except that

309
00:13:44,290 --> 00:13:41,240
the gravitational lensing not only

310
00:13:47,680 --> 00:13:44,300
distorts the light it also magnifies it

311
00:13:50,200 --> 00:13:47,690
each image of this galaxy has been

312
00:13:51,970 --> 00:13:50,210
magnified ten to thirty times brighter

313
00:13:55,420 --> 00:13:51,980

than it otherwise would be

314
00:13:58,180 --> 00:13:55,430
so these galaxy clusters act as lenses

315
00:14:00,490 --> 00:13:58,190
in space to allow us to see yet further

316
00:14:02,830 --> 00:14:00,500
into space than we otherwise would be

317
00:14:04,650 --> 00:14:02,840
able to and here we've got twelve

318
00:14:07,360 --> 00:14:04,660
different images of the same galaxy

319
00:14:09,850 --> 00:14:07,370
stretched out along these various arcs

320
00:14:11,530 --> 00:14:09,860
all right and you know there's there

321
00:14:13,030 --> 00:14:11,540
certain well there's all sorts of

322
00:14:15,460 --> 00:14:13,040
interesting science you can do with that

323
00:14:18,100 --> 00:14:15,470
if you can sit and watch it and monitor

324
00:14:20,410 --> 00:14:18,110
it and see how the various things go but

325
00:14:22,930 --> 00:14:20,420
it also helps you understand the mass

326
00:14:24,940 --> 00:14:22,940
structure of the galaxy itself

327
00:14:27,760 --> 00:14:24,950
so these gravitationally lensed things

328
00:14:29,830 --> 00:14:27,770
can produce these amazing configurations

329
00:14:32,500 --> 00:14:29,840
that give us very precise information

330
00:14:34,570 --> 00:14:32,510
about the structure and shape and mass

331
00:14:37,000 --> 00:14:34,580
distribution of these object located

332
00:14:52,320 --> 00:14:37,010
five billion and even eleven billion

333
00:14:57,730 --> 00:14:54,730
absolutely we wouldn't be able to see it

334
00:14:59,620 --> 00:14:57,740
okay because all 12 images would go down

335
00:15:02,290 --> 00:14:59,630
to one image and that one image would be

336
00:15:02,770 --> 00:15:02,300
very faint and not observable even with

337
00:15:08,740 --> 00:15:02,780
Hubble

338
00:15:10,600 --> 00:15:08,750

can't see this galaxy except for that

339
00:15:12,820 --> 00:15:10,610
its lens and then when you get its lens

340
00:15:19,660 --> 00:15:12,830
it can see twelve images of it which is

341
00:15:21,790 --> 00:15:19,670
kind of cool yeah what kind of

342
00:15:24,310 --> 00:15:21,800
magnitudes are we talking about

343
00:15:27,370 --> 00:15:24,320
Hubble routinely goes down to 26

344
00:15:29,830 --> 00:15:27,380
magnitude two on such year this isn't a

345
00:15:32,500 --> 00:15:29,840
really long exposure we can get to 29th

346
00:15:34,570 --> 00:15:32,510
magnitude on the really long exposure so

347
00:15:36,730 --> 00:15:34,580
but this has got to be the mid one

348
00:15:40,990 --> 00:15:36,740
in terms of magnitudes Serge is nodding

349
00:15:42,160 --> 00:15:41,000
his head he's an observer I'm not it

350
00:15:43,870 --> 00:15:42,170
doesn't know anything about galaxy

351
00:15:47,260 --> 00:15:43,880
there's not stir there's no there no

352
00:15:49,030 --> 00:15:47,270
stars here so he's not gonna comment but

353
00:15:50,650 --> 00:15:49,040
for the for the for the really deep

354
00:15:52,210 --> 00:15:50,660
surveys we can get down to 29 things you

355
00:15:56,170 --> 00:15:52,220
know these have got to be more like you

356
00:15:59,950 --> 00:15:56,180
know 25 26 I think okay all right well

357
00:16:02,200 --> 00:15:59,960
let's move to our featured speaker what

358
00:16:12,009 --> 00:16:02,210
are you on there what number what number

359
00:16:17,809 --> 00:16:15,109
there we go our speaker tonight is Serge

360
00:16:19,850 --> 00:16:17,819
Dietrich who started out his academic

361
00:16:23,299 --> 00:16:19,860
career right across the street at Johns

362
00:16:25,239 --> 00:16:23,309
Hopkins then he left us to go on down to

363
00:16:28,189 --> 00:16:25,249

Georgia State to do his graduate work

364
00:16:30,919 --> 00:16:28,199
where he worked with Todd Henry and the

365
00:16:32,509 --> 00:16:30,929
recons folks down there who've done some

366
00:16:34,910 --> 00:16:32,519
amazing work for a like it's almost 20

367
00:16:37,160 --> 00:16:34,920
years right yeah I've been following

368
00:16:39,710 --> 00:16:37,170
that for quite some time he did a

369
00:16:42,350 --> 00:16:39,720
postdoc at the Carnegie Institute and

370
00:16:43,790 --> 00:16:42,360
then decided to finally come here where

371
00:16:46,160 --> 00:16:43,800
he belongs

372
00:16:51,230 --> 00:16:46,170
he's been here for eight months working

373
00:16:52,879 --> 00:16:51,240
in AI NS on the casa a instrument so

374
00:16:55,400 --> 00:16:52,889
ladies and gentlemen to talk about the

375
00:17:03,710 --> 00:16:55,410
the small stars in our galaxy stairs

376
00:17:04,730 --> 00:17:03,720
Detroit well thank you so much for

377
00:17:08,439 --> 00:17:04,740
coming tonight

378
00:17:11,779 --> 00:17:08,449
AV every good can you hear me yeah okay

379
00:17:14,510 --> 00:17:11,789
so I'll start by saying my my very first

380
00:17:16,490 --> 00:17:14,520
night in in Baltimore was I came for

381
00:17:21,470 --> 00:17:16,500
college orientation and across the

382
00:17:24,829 --> 00:17:21,480
street and I you liked astronomy like

383
00:17:26,899 --> 00:17:24,839
physics and so the thing to do was that

384
00:17:28,880 --> 00:17:26,909
there was one of these lectures here so

385
00:17:31,519 --> 00:17:28,890
those by my very first activity in

386
00:17:33,289 --> 00:17:31,529
Baltimore was attending one of these

387
00:17:36,950 --> 00:17:33,299
lectures I'm not gonna say how many

388
00:17:39,230 --> 00:17:36,960

years ago but I I do see some young

389
00:17:43,549 --> 00:17:39,240
people in the audience so should you

390
00:17:45,139 --> 00:17:43,559
shouts should you so choose I hope to be

391
00:17:47,899 --> 00:17:45,149
here twenty years from now when you are

392
00:17:50,930 --> 00:17:47,909
working here and that that that is a

393
00:17:54,980 --> 00:17:50,940
real watch this is a very welcoming

394
00:17:56,750 --> 00:17:54,990
place so okay so today we're going to

395
00:17:59,539 --> 00:17:56,760
talk about something that we don't hear

396
00:18:02,330 --> 00:17:59,549
a lot and desist ax to twitch are low

397
00:18:04,580 --> 00:18:02,340
mass stars the reason for that is that

398
00:18:06,320 --> 00:18:04,590
most of the researcher virtually all the

399
00:18:09,769 --> 00:18:06,330
research I do and that I'm going to talk

400
00:18:11,510 --> 00:18:09,779
about is ground-based this is just

401
00:18:13,639 --> 00:18:11,520
something we don't we don't use space

402
00:18:16,370 --> 00:18:13,649
telescopes for that much so will be a

403
00:18:17,799 --> 00:18:16,380
little bit of different take on

404
00:18:21,590 --> 00:18:17,809
astronomy

405
00:18:24,740 --> 00:18:21,600
so the first third or so is gonna be a

406
00:18:27,770 --> 00:18:24,750
little bit of a classroom like

407
00:18:31,360 --> 00:18:27,780
sure style we need to get to

408
00:18:33,890 --> 00:18:31,370
understanding what a star really is ah

409
00:18:35,930 --> 00:18:33,900
you've all seen this image is one of the

410
00:18:38,150 --> 00:18:35,940
most famous images by Hubble it's the

411
00:18:41,900 --> 00:18:38,160
pillars of creation and what we're

412
00:18:45,710 --> 00:18:41,910
seeing there is basically the collapse

413
00:18:49,790 --> 00:18:45,720

and contraction of interstellar gas to

414
00:18:52,280 --> 00:18:49,800
form stars and once the gas collapses

415
00:18:55,760 --> 00:18:52,290
and contracts enough it gets hot enough

416
00:18:58,940 --> 00:18:55,770
to ignite nuclear fusion a star is born

417
00:19:01,640 --> 00:18:58,950
and the material eventually dissipates

418
00:19:04,700 --> 00:19:01,650
and we're left with free-floating stars

419
00:19:08,900 --> 00:19:04,710
like the Sun and a hundred billion plus

420
00:19:11,300 --> 00:19:08,910
stars that we haven't in our galaxy this

421
00:19:14,750 --> 00:19:11,310
here is a simulation by a theorist

422
00:19:17,750 --> 00:19:14,760
called Matthew beige out in the United

423
00:19:21,500 --> 00:19:17,760
Kingdom and this is going to give you a

424
00:19:24,650 --> 00:19:21,510
computer rendering of what what the star

425
00:19:29,960 --> 00:19:24,660
formation process looks like so this is

426
00:19:32,420 --> 00:19:29,970
a blob of 500 solar masses and I'm going

427
00:19:38,180 --> 00:19:32,430
to press play now and that blob is going

428
00:19:45,730 --> 00:19:41,260
you

429
00:19:51,869 --> 00:19:45,740
the material the lighter that the more

430
00:20:13,010 --> 00:19:57,830
you

431
00:20:13,020 --> 00:20:24,770
see here goes one and some otters for me

432
00:20:35,430 --> 00:20:29,379
you

433
00:20:42,639 --> 00:20:38,139
so the video is too short so we're gonna

434
00:20:49,100 --> 00:20:42,649
play it again now that you know where

435
00:20:58,299 --> 00:20:54,720
you

436
00:21:06,009 --> 00:21:02,259
and this I heard the years this entire

437
00:21:08,589 --> 00:21:06,019
simulation covers about 200 the first

438
00:21:10,889 --> 00:21:08,599

two hundred thousand years of star

439
00:21:21,520 --> 00:21:10,899
formation is a very very short time

440
00:21:21,530 --> 00:21:36,389
you

441
00:21:43,149 --> 00:21:39,399
so that is where the stars come from

442
00:21:45,999 --> 00:21:43,159
let's look at an individual star right

443
00:21:49,330 --> 00:21:46,009
now there is a characteristic that I'd

444
00:21:51,639 --> 00:21:49,340
like to call stardom for for lack of a

445
00:21:56,049 --> 00:21:51,649
better word what is stardom

446
00:21:58,509 --> 00:21:56,059
what makes an object a star and stars

447
00:22:02,169 --> 00:21:58,519
are actually rather simple objects you

448
00:22:04,989 --> 00:22:02,179
have gravity pulling in as we just saw

449
00:22:08,859 --> 00:22:04,999
in the star formation process and we

450
00:22:14,619 --> 00:22:08,869
have heat gas pressure pushing down

451
00:22:20,289 --> 00:22:14,629
pushing out and as I'm sure all of us

452
00:22:25,840 --> 00:22:20,299
know from you know kindergarten when you

453
00:22:28,479 --> 00:22:25,850
compress a gas it will get it will heat

454
00:22:30,970 --> 00:22:28,489
up you know compressing a gas causes a

455
00:22:32,529 --> 00:22:30,980
temperature to rise I did not learn that

456
00:22:35,529 --> 00:22:32,539
at kindergarten I actually learned that

457
00:22:38,529 --> 00:22:35,539
at Johns Hopkins so somewhere in between

458
00:22:42,639 --> 00:22:38,539
somewhere between so what I have here is

459
00:22:47,369 --> 00:22:42,649
called a fire syringe it's a little toy

460
00:22:51,479 --> 00:22:47,379
to demonstrate that the thing it is a

461
00:22:54,519 --> 00:22:51,489
cylinder inside and an a piston and

462
00:22:59,379 --> 00:22:54,529
inside here I have a little piece of

463
00:23:04,269 --> 00:22:59,389

coffee and the idea is that just like a

464
00:23:06,999 --> 00:23:04,279
star can get so hot to ignite the the

465
00:23:09,399 --> 00:23:07,009
interior we're gonna try to make things

466
00:23:16,790 --> 00:23:09,409
hot enough to ignite this here so could

467
00:23:29,190 --> 00:23:19,380
there's only works about 50% of the time

468
00:23:31,400 --> 00:23:29,200
so I'm taking my chances here so so nice

469
00:23:35,310 --> 00:23:31,410
we can get two out of it

470
00:23:38,520 --> 00:23:35,320
no that wasn't one but basically what

471
00:23:42,270 --> 00:23:38,530
what we just saw here is that if we get

472
00:23:44,520 --> 00:23:42,280
things enough we can get fires and in

473
00:23:47,780 --> 00:23:44,530
the case of stars we can get nuclear

474
00:23:50,100 --> 00:23:47,790
fusion yet so hot no in this case

475
00:23:52,050 --> 00:23:50,110
thankfully it was not nuclear fusion and

476
00:23:57,930 --> 00:23:52,060
otherwise we would not be left for the

477
00:24:01,170 --> 00:23:57,940
Nobel Prize ceremony but and and and so

478
00:24:04,770 --> 00:24:01,180
that is what the Sun is it is an

479
00:24:06,650 --> 00:24:04,780
equilibrium between gravity pulling in

480
00:24:10,770 --> 00:24:06,660
heat pulling out

481
00:24:14,250 --> 00:24:10,780
that's what all stars are but it turns

482
00:24:17,910 --> 00:24:14,260
out that the result of that process is

483
00:24:22,320 --> 00:24:17,920
is very specific it turns out that the

484
00:24:27,270 --> 00:24:22,330
result of this balance only allows for

485
00:24:30,090 --> 00:24:27,280
very certain physical conditions this

486
00:24:33,060 --> 00:24:30,100
here on the left is something called the

487
00:24:36,240 --> 00:24:33,070
hearts firm rustle diagram I like to

488
00:24:40,650 --> 00:24:36,250

think about it as the periodic table as

489
00:24:43,680 --> 00:24:40,660
stellar astronomy if you understand this

490
00:24:46,440 --> 00:24:43,690
diagram and how stars move in this

491
00:24:48,450 --> 00:24:46,450
diagram then you basically understand

492
00:24:52,380 --> 00:24:48,460
most of what there is to know about

493
00:24:55,410 --> 00:24:52,390
stellar theory today we're going to be

494
00:24:58,950 --> 00:24:55,420
focusing on the part there called the

495
00:25:02,250 --> 00:24:58,960
main sequence the main streak across the

496
00:25:04,650 --> 00:25:02,260
diagram the ones on the upper right or

497
00:25:09,660 --> 00:25:04,660
what we thought the Giants they're very

498
00:25:11,940 --> 00:25:09,670
old stars and the ones on the lower I'm

499
00:25:14,790 --> 00:25:11,950
sorry the upper left are the Giants the

500
00:25:17,700 --> 00:25:14,800
ones on the lower right are the white

501
00:25:20,700 --> 00:25:17,710
doors which are dead stars where we

502
00:25:23,990 --> 00:25:20,710
don't care about those today we're gonna

503
00:25:26,340 --> 00:25:24,000
be focusing on the main sequence that is

504
00:25:31,159 --> 00:25:26,350
these stars that are in their adult

505
00:25:38,700 --> 00:25:34,919
the way this diagram works is that the

506
00:25:41,730 --> 00:25:38,710
higher up you are the harder and

507
00:25:46,320 --> 00:25:41,740
brighter you are and also the higher

508
00:25:49,889 --> 00:25:46,330
maps that you have so stars up there

509
00:25:57,749 --> 00:25:49,899
have 30 or 60 times the mass of the Sun

510
00:26:01,139 --> 00:25:57,759
and here's the Sun we're here right in

511
00:26:03,210 --> 00:26:01,149
the middle of the diagram and then the

512
00:26:06,299 --> 00:26:03,220
very tiny stars that we're gonna be

513
00:26:09,600 --> 00:26:06,309

talking about later on on this and

514
00:26:13,049 --> 00:26:09,610
interestingly this axis here the

515
00:26:14,869 --> 00:26:13,059
temperature axis is inverted because

516
00:26:20,369 --> 00:26:14,879
astronomers do not like to do things

517
00:26:22,409 --> 00:26:20,379
simpler so this is hot and this is code

518
00:26:24,749 --> 00:26:22,419
the the real reason for that is because

519
00:26:26,669 --> 00:26:24,759
it was originally a function of

520
00:26:29,580 --> 00:26:26,679
wavelength blue having a shorter

521
00:26:35,220 --> 00:26:29,590
wavelengths then then red but now we

522
00:26:39,919 --> 00:26:35,230
just plot it as hot and code so if we

523
00:26:44,460 --> 00:26:39,929
get these stars and a main-sequence and

524
00:26:47,159 --> 00:26:44,470
we look out into space we look into our

525
00:26:48,590 --> 00:26:47,169
solar neighborhood what do you think

526
00:26:51,749 --> 00:26:48,600
we'll see as far as a stellar

527
00:26:54,269 --> 00:26:51,759
distribution I mean re we often say that

528
00:26:56,669 --> 00:26:54,279
the Sun is an average-sized star but

529
00:27:01,259 --> 00:26:56,679
does that mean we're gonna have just as

530
00:27:03,749 --> 00:27:01,269
many massive stars or there as we have

531
00:27:06,779 --> 00:27:03,759
little stars or how does that

532
00:27:13,259 --> 00:27:06,789
distribution work out the result is

533
00:27:16,799 --> 00:27:13,269
actually very surprising we're gonna do

534
00:27:19,950 --> 00:27:16,809
some abstract art now after I grab my

535
00:27:22,919 --> 00:27:19,960
water I apologize my throat is is very

536
00:27:27,389 --> 00:27:22,929
dry and so I will be taking little

537
00:27:30,649 --> 00:27:27,399
little stops like this this is what we

538
00:27:35,460 --> 00:27:30,659

call the recons marble diagram and

539
00:27:39,149 --> 00:27:35,470
you'll see why in a minute let this star

540
00:27:42,649 --> 00:27:39,159
here represent the Sun both in its size

541
00:27:44,330 --> 00:27:42,659
and in its color

542
00:27:46,849 --> 00:27:44,340
these are the planets of the solar

543
00:27:50,570 --> 00:27:46,859
system so you see how tiny they are

544
00:27:53,779 --> 00:27:50,580
compared to the Sun now we're going to

545
00:27:56,149 --> 00:27:53,789
add to this diagram the other types of

546
00:27:59,960 --> 00:27:56,159
stars within the distance we call ten

547
00:28:03,649 --> 00:27:59,970
parsecs which is about 32 light-years so

548
00:28:05,599 --> 00:28:03,659
imagine our solar neighborhood out 232

549
00:28:11,269 --> 00:28:05,609
light-years well we'll get more to the

550
00:28:12,469 --> 00:28:11,279
explanation of the parsec later on so

551
00:28:16,009 --> 00:28:12,479
the first thing we're going to do is

552
00:28:19,159 --> 00:28:16,019
we're gonna add those dead stars called

553
00:28:22,489 --> 00:28:19,169
the white dwarfs they are tiny they are

554
00:28:23,810 --> 00:28:22,499
about the size of Earth and here we have

555
00:28:28,940 --> 00:28:23,820
about 20 of them

556
00:28:33,190 --> 00:28:28,950
oh and B stars are the massive most

557
00:28:35,509 --> 00:28:33,200
bigger most larger stars in the universe

558
00:28:37,219 --> 00:28:35,519
we don't have any of those in the solar

559
00:28:41,109 --> 00:28:37,229
neighborhood and it's probably a good

560
00:28:47,839 --> 00:28:44,419
next comes the F stars which are also

561
00:28:48,379 --> 00:28:47,849
very massive not as much we have four of

562
00:28:51,349 --> 00:28:48,389
those

563
00:28:53,930 --> 00:28:51,359

they shine very very white they're this

564
00:28:56,779 --> 00:28:53,940
hot white china and you see they're

565
00:29:00,890 --> 00:28:56,789
about two times or more the size of the

566
00:29:05,659 --> 00:29:03,500
I'm sorry those were the a stars here we

567
00:29:09,049 --> 00:29:05,669
have the app stars so you see the

568
00:29:13,850 --> 00:29:09,059
numbers are getting a little bigger as

569
00:29:21,399 --> 00:29:13,860
we go along those are the solar-type

570
00:29:27,019 --> 00:29:24,169
smaller than a Sun we have the K type

571
00:29:30,470 --> 00:29:27,029
stars and you see we went from four to

572
00:29:32,539 --> 00:29:30,480
six to 20 to 40 so as we're going

573
00:29:36,080 --> 00:29:32,549
smaller and cooler things are really

574
00:29:39,880 --> 00:29:36,090
picking up here on size I'm going to add

575
00:29:48,639 --> 00:29:39,890
the m-type stars which are the smallest

576
00:29:51,830 --> 00:29:48,649
types of stars that that form 240 stakes

577
00:29:54,740 --> 00:29:51,840
70% of the stars in our solar

578
00:29:59,299 --> 00:29:54,750
neighborhood and by extension in in our

579
00:30:01,519 --> 00:29:59,309
galaxy are very low mass stars with

580
00:30:05,440 --> 00:30:01,529
masses anywhere from about half that of

581
00:30:09,710 --> 00:30:05,450
the Sun to about 7% the mass of the Sun

582
00:30:11,419 --> 00:30:09,720
so chances are you know if you were God

583
00:30:13,100 --> 00:30:11,429
and you close your eyes and you reached

584
00:30:16,549 --> 00:30:13,110
in the galaxy and picked up a random

585
00:30:19,610 --> 00:30:16,559
star it would not be our average Sun it

586
00:30:22,970 --> 00:30:19,620
would be an M star which these stars are

587
00:30:27,169 --> 00:30:22,980
you know very small we're gonna talk

588
00:30:29,090 --> 00:30:27,179

about just how small and very cool but

589
00:30:32,419 --> 00:30:29,100
they're also very long-lived

590
00:30:35,450 --> 00:30:32,429
so they are perhaps a good place for

591
00:30:41,230 --> 00:30:35,460
habitable planets perhaps there's the

592
00:30:46,190 --> 00:30:41,240
beige on that so let's go back to this

593
00:30:50,570 --> 00:30:46,200
cylinder here earlier I pressed it

594
00:30:53,029 --> 00:30:50,580
enough that we had what we pretended was

595
00:30:56,750 --> 00:30:53,039
nuclear ignition inside it was not but

596
00:31:01,310 --> 00:30:56,760
we pretended that what if I press this

597
00:31:04,159 --> 00:31:01,320
down but I was not strong enough I did

598
00:31:08,389 --> 00:31:04,169
not have enough gravity to get to that

599
00:31:10,220 --> 00:31:08,399
point of nuclear ignition it still got

600
00:31:12,350 --> 00:31:10,230
hotter in fact touching this right now

601
00:31:14,190 --> 00:31:12,360
it is hot just because of the fact that

602
00:31:18,539 --> 00:31:14,200
I compressed it

603
00:31:21,149 --> 00:31:18,549
but you may remember that that that I

604
00:31:28,139 --> 00:31:21,159
gave on it was was quite strong to make

605
00:31:32,519 --> 00:31:28,149
it ignite so enter in the brown dwarfs

606
00:31:35,580 --> 00:31:32,529
the brown dwarfs are failed stars the

607
00:31:38,340 --> 00:31:35,590
brown dwarfs are remnants of the stellar

608
00:31:40,950 --> 00:31:38,350
formation process when the cylinder

609
00:31:43,919 --> 00:31:40,960
basically did not get all the way down

610
00:31:47,359 --> 00:31:43,929
for nuclear ignition the thing to

611
00:31:50,190 --> 00:31:47,369
remember the important thing is that

612
00:31:52,289 --> 00:31:50,200
compressing it still made it hot so

613
00:31:54,060 --> 00:31:52,299

there are not necessarily cold objects

614
00:31:56,970 --> 00:31:54,070
they're not like the white dwarfs that

615
00:31:58,169 --> 00:31:56,980
are just you know floating stellar

616
00:31:59,759 --> 00:31:58,179
cadavers

617
00:32:01,859 --> 00:31:59,769
basically I mean that is not my term

618
00:32:08,129 --> 00:32:01,869
people actually use that term stellar

619
00:32:10,019 --> 00:32:08,139
whatever as gross as it may sound so

620
00:32:12,419 --> 00:32:10,029
electron degeneracy pressure basically

621
00:32:15,539 --> 00:32:12,429
gas pressure you know solid pressure

622
00:32:20,009 --> 00:32:15,549
stops the contraction before the nuclear

623
00:32:24,690 --> 00:32:20,019
ignition happens you do have this burst

624
00:32:26,849 --> 00:32:24,700
of heat in the beginning but there is no

625
00:32:29,810 --> 00:32:26,859
nuclear fusion so they start very hot

626
00:32:34,019 --> 00:32:29,820
and then they just cool down forever

627
00:32:37,590 --> 00:32:34,029
this image here the one on the right

628
00:32:41,090 --> 00:32:37,600
taken with a ground-based Observatory

629
00:32:43,769 --> 00:32:41,100
the one on the left taken by HST in 1995

630
00:32:46,169 --> 00:32:43,779
was the discovery image of the first

631
00:32:49,590 --> 00:32:46,179
round or these objects had been

632
00:32:52,919 --> 00:32:49,600
theorized for ever since the 60s but

633
00:32:55,340 --> 00:32:52,929
then in 1995 david golub mouseski who

634
00:32:57,840 --> 00:32:55,350
now is a scientist here he was a

635
00:33:01,379 --> 00:32:57,850
graduate student at Johns Hopkins at the

636
00:33:04,019 --> 00:33:01,389
time was able to pin one down and show

637
00:33:06,479 --> 00:33:04,029
that they actually exist in this case it

638
00:33:11,789 --> 00:33:06,489

was an orbit around a much more massive

639
00:33:16,409 --> 00:33:11,799
star that round orifice is this it's the

640
00:33:18,060 --> 00:33:16,419
tiny one and we know now that most of

641
00:33:19,499 --> 00:33:18,070
them are actually not in orbit around

642
00:33:28,720 --> 00:33:19,509
other stars they're just free-floating

643
00:33:35,120 --> 00:33:32,120
so and they they get to be really small

644
00:33:40,100 --> 00:33:35,130
they got to be about the size of Jupiter

645
00:33:42,530 --> 00:33:40,110
and their ring is is actually mostly

646
00:33:44,060 --> 00:33:42,540
constant doesn't vary much but the weird

647
00:33:46,460 --> 00:33:44,070
thing about them is because of their

648
00:33:48,950 --> 00:33:46,470
internal physics when you put more mass

649
00:33:52,130 --> 00:33:48,960
into them they actually shrink they get

650
00:33:54,650 --> 00:33:52,140
more compressed so they're very weird

651
00:33:56,720 --> 00:33:54,660
objects and we still don't fully

652
00:33:59,060 --> 00:33:56,730
understand them they are difficult to

653
00:34:05,600 --> 00:33:59,070
study because they are so faint as as

654
00:34:08,240 --> 00:34:05,610
well let's look at the bottom here first

655
00:34:12,500 --> 00:34:08,250
those are just artist conceptions of

656
00:34:15,830 --> 00:34:12,510
what these objects would look like an M

657
00:34:18,770 --> 00:34:15,840
star is one of those very small stars

658
00:34:22,100 --> 00:34:18,780
that I mentioned would be sort of a

659
00:34:23,870 --> 00:34:22,110
yellowish reddish orangish color we

660
00:34:27,670 --> 00:34:23,880
think that they have a lot of spots on

661
00:34:31,280 --> 00:34:27,680
them does the band's of spots here and

662
00:34:34,190 --> 00:34:31,290
then for the brown doors we classify

663
00:34:36,620 --> 00:34:34,200

them in in three different letters of

664
00:34:39,880 --> 00:34:36,630
the sequence we have the so called L

665
00:34:43,790 --> 00:34:39,890
dwarfs which are harder round orbs as

666
00:34:47,780 --> 00:34:43,800
they cool down they turn into T dwarfs

667
00:34:49,970 --> 00:34:47,790
and then eventually they become very

668
00:34:53,230 --> 00:34:49,980
cold objects almost the temperature the

669
00:34:56,300 --> 00:34:53,240
earth called Y dwarfs letter Y not white

670
00:34:58,490 --> 00:34:56,310
where do these letters come from this I

671
00:35:00,860 --> 00:34:58,500
know the person who picked those letters

672
00:35:02,630 --> 00:35:00,870
they literally open the index of an

673
00:35:06,620 --> 00:35:02,640
astronomy book and salt which letters

674
00:35:09,470 --> 00:35:06,630
were left no it is a true story those

675
00:35:12,530 --> 00:35:09,480
are letters not used for other things in

676
00:35:19,760 --> 00:35:12,540
in astronomy so that's there is no no

677
00:35:21,260 --> 00:35:19,770
logical sense to them the L doors is

678
00:35:24,770 --> 00:35:21,270
what we're going to be focusing on for

679
00:35:27,430 --> 00:35:24,780
the rest of the class the elders are

680
00:35:31,100 --> 00:35:27,440
really a mix of different things

681
00:35:33,560 --> 00:35:31,110
depending on the type of object an elder

682
00:35:35,930 --> 00:35:33,570
earth could be either a very very young

683
00:35:38,520 --> 00:35:35,940
planet in the Stars only a few million

684
00:35:42,900 --> 00:35:38,530
years old it could be

685
00:35:46,290 --> 00:35:42,910
a very low-mass star an object in which

686
00:35:49,560 --> 00:35:46,300
nuclear fusion does happen or it could

687
00:35:51,990 --> 00:35:49,570
also be a young brown dwarf so the

688
00:35:54,870 --> 00:35:52,000

question is you know like if we have

689
00:35:57,120 --> 00:35:54,880
this overlap of objects how do we

690
00:35:59,760 --> 00:35:57,130
distinguish them how do we know where

691
00:36:03,630 --> 00:35:59,770
the stars end and where the brown dwarfs

692
00:36:06,900 --> 00:36:03,640
begin that is actually the science

693
00:36:09,540 --> 00:36:06,910
question for this talk that is this was

694
00:36:12,870 --> 00:36:09,550
the topic of my PhD thesis it's what

695
00:36:14,430 --> 00:36:12,880
we're going to be addressing here I'm

696
00:36:17,340 --> 00:36:14,440
going to read this question a few

697
00:36:19,580 --> 00:36:17,350
different ways no you'll have to read

698
00:36:22,710 --> 00:36:19,590
that this because you've read it but

699
00:36:26,430 --> 00:36:22,720
another way of saying this is what is

700
00:36:28,710 --> 00:36:26,440
the smallest star I talked about the

701
00:36:31,410 --> 00:36:28,720
property of stardom which is basically

702
00:36:38,400 --> 00:36:31,420
an object that enters the main sequence

703
00:36:40,110 --> 00:36:38,410
and and burns fuses hydrogen how small

704
00:36:51,110 --> 00:36:40,120
and what are the characteristics of that

705
00:36:58,260 --> 00:36:55,830
mentioned earlier that the HR diagram is

706
00:37:01,320 --> 00:36:58,270
the periodic table of stellar astronomy

707
00:37:04,200 --> 00:37:01,330
and if you're going to know anything

708
00:37:07,160 --> 00:37:04,210
about a star you need to first

709
00:37:11,520 --> 00:37:07,170
understand how it fits in the HR diagram

710
00:37:13,950 --> 00:37:11,530
so that is what we're going to do here

711
00:37:16,290 --> 00:37:13,960
we're going to place a bunch of Brown

712
00:37:18,660 --> 00:37:16,300
doors and a bunch of very low mass stars

713
00:37:23,160 --> 00:37:18,670

without knowing what they are a priori

714
00:37:28,830 --> 00:37:23,170
on the HR diagram and then we're gonna

715
00:37:30,930 --> 00:37:28,840
see if any patterns come out and no when

716
00:37:34,380 --> 00:37:30,940
I was talking with my adviser Todd Henry

717
00:37:36,420 --> 00:37:34,390
and and we were thinking about how to do

718
00:37:39,720 --> 00:37:36,430
this project it's like yeah let's just

719
00:37:42,180 --> 00:37:39,730
place them on the HR diagram and I was

720
00:37:43,560 --> 00:37:42,190
like what if you know they're just dots

721
00:37:46,890 --> 00:37:43,570
on the diagram and nothing comes out

722
00:37:49,320 --> 00:37:46,900
says like there is no such thing about

723
00:37:52,160 --> 00:37:49,330
as putting something in the HR diagram

724
00:37:55,820 --> 00:37:52,170
without finding something about it

725
00:37:58,190 --> 00:37:55,830
it is a very useful tool so he said just

726
00:38:01,040 --> 00:37:58,200
put those dots in the HR diagram and

727
00:38:05,180 --> 00:38:01,050
something will come out some pattern to

728
00:38:08,090 --> 00:38:05,190
distinguish them welcome out so what do

729
00:38:10,340 --> 00:38:08,100
we need to what sorts of observations do

730
00:38:13,820 --> 00:38:10,350
we actually need to place a star in the

731
00:38:16,280 --> 00:38:13,830
HR diagram the horizontal axis is all

732
00:38:18,350 --> 00:38:16,290
about color the call or the objects

733
00:38:22,850 --> 00:38:18,360
bloom or objects being hotter objects

734
00:38:26,720 --> 00:38:22,860
redder objects being cooler objects the

735
00:38:28,970 --> 00:38:26,730
brightness access is a combination of

736
00:38:32,900 --> 00:38:28,980
how intrinsically bright an object is

737
00:38:35,000 --> 00:38:32,910
and also how distant it is you know like

738
00:38:37,640 --> 00:38:35,010

you don't you don't know the distance

739
00:38:40,250 --> 00:38:37,650
the Stars a priori you don't know if it

740
00:38:43,820 --> 00:38:40,260
is something very large and bright right

741
00:38:45,380 --> 00:38:43,830
next to you or like very far away or if

742
00:38:48,230 --> 00:38:45,390
it's you know like a firefly that

743
00:38:48,590 --> 00:38:48,240
happens to be flying right in front of

744
00:38:52,250 --> 00:38:48,600
you

745
00:38:54,130 --> 00:38:52,260
so getting distances to those objects is

746
00:39:02,390 --> 00:38:54,140
going to be a major part of this

747
00:39:03,890 --> 00:39:02,400
observational effort skip this light so

748
00:39:05,900 --> 00:39:03,900
I was thinking about what to actually

749
00:39:07,760 --> 00:39:05,910
present as far as the observation goes

750
00:39:08,540 --> 00:39:07,770
and and and I felt like okay well I

751
00:39:12,310 --> 00:39:08,550
could borrow

752
00:39:15,800 --> 00:39:12,320
I could bore these folks with a lot of

753
00:39:17,810 --> 00:39:15,810
mathematics and all things like that or

754
00:39:20,990 --> 00:39:17,820
we could talk about something much

755
00:39:22,640 --> 00:39:21,000
cooler which is observatories as I

756
00:39:25,070 --> 00:39:22,650
mentioned earlier do you know because of

757
00:39:28,480 --> 00:39:25,080
the nature does Institute we don't get a

758
00:39:30,500 --> 00:39:28,490
lot of ground-based astronomy here so

759
00:39:33,590 --> 00:39:30,510
I'd like to take a break from the

760
00:39:36,110 --> 00:39:33,600
science now and very quickly tell you

761
00:39:38,300 --> 00:39:36,120
what observatories are like because

762
00:39:40,700 --> 00:39:38,310
they're really magical places they are

763
00:39:42,890 --> 00:39:40,710

truly wonderful places if you ever have

764
00:39:46,310 --> 00:39:42,900
the opportunity to visit a professional

765
00:39:49,460 --> 00:39:46,320
Observatory I highly recommend it

766
00:39:52,190 --> 00:39:49,470
this work was all done in Chile it turns

767
00:39:55,190 --> 00:39:52,200
out that having high mountains right

768
00:39:58,370 --> 00:39:55,200
next to the ocean makes for very stable

769
00:40:00,260 --> 00:39:58,380
atmosphere the places like that or

770
00:40:03,260 --> 00:40:00,270
California which unfortunately is like

771
00:40:05,430 --> 00:40:03,270
polluted Hawaii which is an order very

772
00:40:07,770 --> 00:40:05,440
good observing location

773
00:40:10,590 --> 00:40:07,780
and the capital of observational

774
00:40:14,730 --> 00:40:10,600
astronomy actually is chilly ah

775
00:40:17,330 --> 00:40:14,740
all major observatories are all major

776
00:40:20,670 --> 00:40:17,340
institutions ground-based observing have

777
00:40:24,150 --> 00:40:20,680
observatories in Chile so these are two

778
00:40:27,570 --> 00:40:24,160
of the telescope's that are used these

779
00:40:30,870 --> 00:40:27,580
are some images from Cerro to Lolo

780
00:40:33,840 --> 00:40:30,880
Observatory that is the US National

781
00:40:36,450 --> 00:40:33,850
Observatory for the southern hemisphere

782
00:40:40,230 --> 00:40:36,460
so the u.s. actually has a partnership

783
00:40:42,540 --> 00:40:40,240
with Chile u.s. goes there you know pays

784
00:40:45,870 --> 00:40:42,550
for everything runs for everything and

785
00:40:49,200 --> 00:40:45,880
Chile as the host for welcoming us gets

786
00:40:51,690 --> 00:40:49,210
10% of the time of the telescope's so

787
00:40:54,240 --> 00:40:51,700
Chilean astronomy is is actually very

788
00:40:56,940 --> 00:40:54,250

active because they have 10% of the

789
00:40:58,560 --> 00:40:56,950
resources from really all over the world

790
00:41:00,930 --> 00:40:58,570
all countries are putting those

791
00:41:03,330 --> 00:41:00,940
telescopes there and they don't have to

792
00:41:07,440 --> 00:41:03,340
fund any of it you know they just get it

793
00:41:10,110 --> 00:41:07,450
for for being good hosts this is the top

794
00:41:12,000 --> 00:41:10,120
of the mountain it is roughly eight

795
00:41:15,000 --> 00:41:12,010
thousand feet the top of the mountain is

796
00:41:17,720 --> 00:41:15,010
basically chopped off and there you have

797
00:41:20,790 --> 00:41:17,730
the the several telescopes there about

798
00:41:25,290 --> 00:41:20,800
20 or so telescopes and in this

799
00:41:27,060 --> 00:41:25,300
Observatory this telescope here during

800
00:41:29,820 --> 00:41:27,070
graduate school was home away from home

801
00:41:31,590 --> 00:41:29,830
I would I actually had a box that I left

802
00:41:32,700 --> 00:41:31,600
there with my toothbrush and things like

803
00:41:35,520 --> 00:41:32,710
that so I didn't have to carry it

804
00:41:38,460 --> 00:41:35,530
because for about half the year I was I

805
00:41:41,190 --> 00:41:38,470
was there that's the image of a typical

806
00:41:42,720 --> 00:41:41,200
meter class telescope so when we talk

807
00:41:45,150 --> 00:41:42,730
about the sizes of telescopes we're

808
00:41:47,760 --> 00:41:45,160
talking about the diameter of the

809
00:41:51,030 --> 00:41:47,770
primary mirror some one we say a meter

810
00:41:55,050 --> 00:41:51,040
it's not length it is you know this the

811
00:41:56,370 --> 00:41:55,060
eye of the telescope and one of the

812
00:42:00,000 --> 00:41:56,380
really cool things about these small

813
00:42:02,910 --> 00:42:00,010

telescopes is that the astronomer still

814
00:42:04,710 --> 00:42:02,920
gets to use it for him or herself you

815
00:42:07,920 --> 00:42:04,720
still get to actually press the buttons

816
00:42:10,470 --> 00:42:07,930
and tell the telescopes were were to

817
00:42:11,880 --> 00:42:10,480
move you know like I do work here they

818
00:42:16,350 --> 00:42:11,890
do not let me do that with a bow

819
00:42:19,020 --> 00:42:16,360
unfortunately but even in larger

820
00:42:20,730 --> 00:42:19,030
ground-based telescopes the telescope

821
00:42:24,090 --> 00:42:20,740
itself be controlled by an engineer

822
00:42:26,340 --> 00:42:24,100
telescope operator and then you will be

823
00:42:27,420 --> 00:42:26,350
controlling the camera at the end of

824
00:42:30,030 --> 00:42:27,430
that telescope

825
00:42:32,430 --> 00:42:30,040
in this telescope you know if it breaks

826
00:42:35,180 --> 00:42:32,440
it's my problem because I'm the only one

827
00:42:40,320 --> 00:42:35,190
there I have to be able to do everything

828
00:42:42,780 --> 00:42:40,330
just another pretty picture where this

829
00:42:44,820 --> 00:42:42,790
is looking towards the Andes so towards

830
00:42:47,130 --> 00:42:44,830
Argentina and the back of those

831
00:42:50,420 --> 00:42:47,140
mountains this was summer

832
00:42:56,310 --> 00:42:50,430
if it was winter would be all covered in

833
00:42:58,770 --> 00:42:56,320
snow going a little bit further north

834
00:43:01,220 --> 00:42:58,780
this is an observatory called Las

835
00:43:04,230 --> 00:43:01,230
Campanas where I did my first postdoc

836
00:43:06,600 --> 00:43:04,240
these were panoramic images but you can

837
00:43:10,170 --> 00:43:06,610
see that it is above the clouds most

838
00:43:12,510 --> 00:43:10,180

days you will wake up and you will look

839
00:43:14,670 --> 00:43:12,520
down at the clouds and it's it's a

840
00:43:18,690 --> 00:43:14,680
wonderful experience just to be in a

841
00:43:21,060 --> 00:43:18,700
place like that and you know you look in

842
00:43:22,860 --> 00:43:21,070
the satellite image and say like oh it's

843
00:43:24,420 --> 00:43:22,870
cloudy we're not gonna be observing

844
00:43:25,980 --> 00:43:24,430
tonight and you have to realize that it

845
00:43:33,870 --> 00:43:25,990
is cloudy but the clouds are below you

846
00:43:36,110 --> 00:43:33,880
so this is a nodder image of a typical

847
00:43:39,420 --> 00:43:36,120
meter sized telescope again the

848
00:43:42,540 --> 00:43:39,430
telescope that you know it is great for

849
00:43:44,220 --> 00:43:42,550
training students because in order to

850
00:43:46,260 --> 00:43:44,230
use a telescope like this you actually

851
00:43:48,960 --> 00:43:46,270
need to know where the sky is like you

852
00:43:51,390 --> 00:43:48,970
need to know where your star is and

853
00:43:53,160 --> 00:43:51,400
which way pointing like you ask people

854
00:43:55,680 --> 00:43:53,170
who use hub oh you know eye is your

855
00:43:56,970 --> 00:43:55,690
target in the northern hemisphere or in

856
00:43:58,590 --> 00:43:56,980
the southern hemisphere

857
00:44:01,920 --> 00:43:58,600
well Hubble covers both hemispheres

858
00:44:05,970 --> 00:44:01,930
every 90 minutes why why would you care

859
00:44:08,510 --> 00:44:05,980
right though it is a connection that you

860
00:44:11,910 --> 00:44:08,520
get to nature to both earth and the sky

861
00:44:14,070 --> 00:44:11,920
that you just don't get with space-based

862
00:44:17,880 --> 00:44:14,080
astronomy space-based astronomy is of

863
00:44:22,920 --> 00:44:17,890

course much more powerful but it's it's

864
00:44:25,350 --> 00:44:22,930
not a spine okay I just had it so these

865
00:44:27,510 --> 00:44:25,360
these observatories are like small

866
00:44:30,960 --> 00:44:27,520
cities the people who work there are

867
00:44:32,370 --> 00:44:30,970
usually there for about or for exactly a

868
00:44:37,680 --> 00:44:32,380
week

869
00:44:40,589 --> 00:44:37,690
and at any time you may have about a

870
00:44:42,719 --> 00:44:40,599
hundred people or so working there this

871
00:44:45,239 --> 00:44:42,729
is looking down to what we called the

872
00:44:49,259 --> 00:44:45,249
lodge this is the dining area and all

873
00:44:50,910 --> 00:44:49,269
the dorm rooms and this is basically

874
00:44:53,430 --> 00:44:50,920
where the party happens you know like

875
00:44:54,989 --> 00:44:53,440
we're saying this is a geek fest well we

876
00:44:57,329 --> 00:44:54,999
don't have anything on these

877
00:44:59,190 --> 00:44:57,339
observatories I mean imagine going there

878
00:45:03,680 --> 00:44:59,200
being away from family away from

879
00:45:07,739 --> 00:45:03,690
everything and just with your friends

880
00:45:09,390 --> 00:45:07,749
eating talking and observing and not

881
00:45:10,440 --> 00:45:09,400
really worry about the results too much

882
00:45:13,190 --> 00:45:10,450
because who's going to do that when you

883
00:45:18,839 --> 00:45:13,200
get back to your office so it is a very

884
00:45:21,959 --> 00:45:18,849
fast-paced life but it is it's a lot of

885
00:45:25,650 --> 00:45:21,969
fun and in this case here those were all

886
00:45:29,249 --> 00:45:25,660
my friends who I usually only see when I

887
00:45:33,420 --> 00:45:29,259
go to the observatory so it's just a

888
00:45:35,219 --> 00:45:33,430

very inspiring place like that we do not

889
00:45:38,880 --> 00:45:35,229
use gasoline or anything like that we

890
00:45:40,589 --> 00:45:38,890
use coffee whenever you see a coffee

891
00:45:42,329 --> 00:45:40,599
machine there's gonna be two of them

892
00:45:47,009 --> 00:45:42,339
because if one of them breaks the

893
00:45:50,009 --> 00:45:47,019
Observatory shuts down so you know it

894
00:45:52,680 --> 00:45:50,019
can be challenging to shift your

895
00:45:55,349 --> 00:45:52,690
schedule you're usually coming from a 10

896
00:45:56,729 --> 00:45:55,359
hour plane ride and then you know you're

897
00:45:58,979 --> 00:45:56,739
shifting to a night schedule and you're

898
00:46:01,170 --> 00:45:58,989
dealing without that you to splice is

899
00:46:05,579 --> 00:46:01,180
about three hundred three thousand

900
00:46:10,620 --> 00:46:05,589
meters I so a you do need the coffee to

901
00:46:13,079 --> 00:46:10,630
to get going this is what a typical

902
00:46:16,680 --> 00:46:13,089
control room for small telescope would

903
00:46:20,009 --> 00:46:16,690
look like so what we're seeing on the

904
00:46:22,680 --> 00:46:20,019
left there is inside the dome and what

905
00:46:25,229 --> 00:46:22,690
we're seeing on the right here is under

906
00:46:27,029 --> 00:46:25,239
the dome very few astronomers even

907
00:46:30,420 --> 00:46:27,039
ground-based are actually going to look

908
00:46:32,339 --> 00:46:30,430
through a telescope eyepiece anymore you

909
00:46:34,140 --> 00:46:32,349
only do that when the telescope has lost

910
00:46:36,539 --> 00:46:34,150
this tracking and you need to find a

911
00:46:39,660 --> 00:46:36,549
bright start to align it all the science

912
00:46:41,339 --> 00:46:39,670
is done through computer images and that

913
00:46:43,390 --> 00:46:41,349

and in that sense it is very much like

914
00:46:46,329 --> 00:46:43,400
space images

915
00:46:49,180 --> 00:46:46,339
and another cool thing about these small

916
00:46:51,849 --> 00:46:49,190
telescopes is that it's easier to get

917
00:46:54,519 --> 00:46:51,859
the time they're usually undersubscribed

918
00:46:57,460 --> 00:46:54,529
so you have a lot more flexibility what

919
00:46:59,019 --> 00:46:57,470
you want to do with them and since I had

920
00:47:03,029 --> 00:46:59,029
like over a hundred nights and thus

921
00:47:07,329 --> 00:47:03,039
telescope every now and then I would

922
00:47:09,759 --> 00:47:07,339
allow myself to do some fun so this is

923
00:47:13,359 --> 00:47:09,769
an image of the sombrero galaxy and they

924
00:47:15,489 --> 00:47:13,369
said after a 10:00 night observing run

925
00:47:16,960 --> 00:47:15,499
that had gone really well so like you

926
00:47:20,319 --> 00:47:16,970
know what last thing I'm gonna do was

927
00:47:23,410 --> 00:47:20,329
save half an hour to myself and just do

928
00:47:30,519 --> 00:47:23,420
a pretty image so I did that and again

929
00:47:33,700 --> 00:47:30,529
on Hubble they don't let you do that so

930
00:47:37,539 --> 00:47:33,710
I see by the age here the crowd that

931
00:47:39,249 --> 00:47:37,549
you're gonna laugh at me right and just

932
00:47:40,539 --> 00:47:39,259
as I was leaving they said oh by the way

933
00:47:44,470 --> 00:47:40,549
all the cars in the Observatory

934
00:47:47,589 --> 00:47:44,480
restrictions and so this was a lunch

935
00:47:49,420 --> 00:47:47,599
table and half of us were American half

936
00:47:52,120 --> 00:47:49,430
of us were European at the table I asked

937
00:47:54,970 --> 00:47:52,130
everyone and and the division was start

938
00:47:56,859 --> 00:47:54,980

all Europeans said that I had to pay an

939
00:47:58,720 --> 00:47:56,869
instructor and get a week's worth of

940
00:48:00,549 --> 00:47:58,730
classes before I would go or the

941
00:48:05,170 --> 00:48:00,559
Americans like I just go you figure it

942
00:48:07,420 --> 00:48:05,180
out and me being the American I I figure

943
00:48:12,009 --> 00:48:07,430
like okay well I will learn to drive the

944
00:48:18,579 --> 00:48:12,019
Observatory car on the fly and this will

945
00:48:22,950 --> 00:48:18,589
happen so this is the very first

946
00:48:26,460 --> 00:48:22,960
impression I made on the observatory and

947
00:48:29,259 --> 00:48:26,470
they still asked me back so it was good

948
00:48:31,539 --> 00:48:29,269
no one was hurt I was actually not in

949
00:48:38,559 --> 00:48:31,549
the car I was pushing the car in the car

950
00:48:41,349 --> 00:48:38,569
storage so yeah this was not a good

951
00:48:43,599 --> 00:48:41,359
night for observing this was a very

952
00:48:45,880 --> 00:48:43,609
pretty sunset but we call sunsets like

953
00:48:47,470 --> 00:48:45,890
this consolation prizes it's like okay

954
00:48:52,809 --> 00:48:47,480
well we're not gonna observe tonight it

955
00:48:55,299 --> 00:48:52,819
might as well be pretty this little guys

956
00:48:56,990 --> 00:48:55,309
called viscacha it is a relative

957
00:48:59,600 --> 00:48:57,000
reduction chillin

958
00:49:03,170 --> 00:48:59,610
it lives in the Andes it is about this

959
00:49:06,830 --> 00:49:03,180
big so it's kind of like a big bunny

960
00:49:08,660 --> 00:49:06,840
with a squirrel tail and cool thing

961
00:49:09,470 --> 00:49:08,670
about them is that they actually watch

962
00:49:11,510 --> 00:49:09,480
the sunset

963
00:49:14,330 --> 00:49:11,520

they live in these crevasses and rocks

964
00:49:16,160 --> 00:49:14,340
and they come out for the sunset and

965
00:49:17,960 --> 00:49:16,170
they will just stand there I mean who

966
00:49:23,030 --> 00:49:17,970
knows if they're actively watching it or

967
00:49:25,820 --> 00:49:23,040
not but the other nice fauna that we

968
00:49:29,090 --> 00:49:25,830
have there is this is a guanaco which is

969
00:49:34,430 --> 00:49:29,100
a wildly ama so and this is actually a

970
00:49:36,590 --> 00:49:34,440
video so play it's my neighbor are right

971
00:49:55,860 --> 00:49:36,600
outside my door Mike came out one day

972
00:50:01,690 --> 00:49:58,450
so again one of the things that really

973
00:50:05,140 --> 00:50:01,700
fascinates me about astronomy is is the

974
00:50:08,830 --> 00:50:05,150
the earth to sky connection you know

975
00:50:12,430 --> 00:50:08,840
where were in this place you know dirt

976
00:50:13,920 --> 00:50:12,440
roads rocks everywhere our neighbors

977
00:50:17,980 --> 00:50:13,930
actually don't have electricity there

978
00:50:20,290 --> 00:50:17,990
goes herders goat herders and and yet

979
00:50:24,250 --> 00:50:20,300
here we are you know like reaching out

980
00:50:25,540 --> 00:50:24,260
toward to the stars I think that there

981
00:50:27,670 --> 00:50:25,550
was something with the section about

982
00:50:29,860 --> 00:50:27,680
bringing it together in the

983
00:50:31,750 --> 00:50:29,870
observatories and and again if you ever

984
00:50:33,850 --> 00:50:31,760
have the the opportunity to go to a

985
00:50:36,040 --> 00:50:33,860
professional observatory most of them

986
00:50:38,550 --> 00:50:36,050
will walk for tours just call them up I

987
00:50:46,660 --> 00:50:38,560
highly recommend it because it is a

988
00:50:54,310 --> 00:50:46,670

really nice experience but breaks over

989
00:50:56,950 --> 00:50:54,320
back to the science so I mentioned

990
00:51:00,220 --> 00:50:56,960
earlier that we needed to know both how

991
00:51:03,610 --> 00:51:00,230
bright those stars are and the distances

992
00:51:10,450 --> 00:51:03,620
to these stars in order to put them in

993
00:51:12,310 --> 00:51:10,460
this axis here distances are a little

994
00:51:14,200 --> 00:51:12,320
bit more fun than just brightness s so

995
00:51:19,720 --> 00:51:14,210
let's talk a little bit about how we get

996
00:51:21,360 --> 00:51:19,730
distances to stars may have heard this

997
00:51:24,130 --> 00:51:21,370
before it's a technique called

998
00:51:28,590 --> 00:51:24,140
trigonometric parallax and it is just

999
00:51:32,530 --> 00:51:28,600
simple geometry that goes on it as Earth

1000
00:51:36,010 --> 00:51:32,540
leaves around its orbit our line of

1001
00:51:38,740 --> 00:51:36,020
sight to a nearby star changes we're in

1002
00:51:43,540 --> 00:51:38,750
this point in the orbit and we're

1003
00:51:45,070 --> 00:51:43,550
looking at a nearby star the stars in

1004
00:51:47,080 --> 00:51:45,080
the background that we're going to see

1005
00:51:50,290 --> 00:51:47,090
are going to be slightly shifted and

1006
00:51:53,260 --> 00:51:50,300
again it is we are moving the stars

1007
00:51:55,840 --> 00:51:53,270
themselves are not moving this is where

1008
00:51:58,470 --> 00:51:55,850
the definition of this funny distance

1009
00:52:02,100 --> 00:51:58,480
unit called our stack comes from a

1010
00:52:06,520 --> 00:52:02,110
parsec is the distance at which a star

1011
00:52:07,440 --> 00:52:06,530
will have a parallax Wabo equal to one

1012
00:52:20,940 --> 00:52:07,450
second

1013
00:52:23,790 --> 00:52:20,950

where where's my wallet sorry should've

1014
00:52:27,240 --> 00:52:23,800
kept it but if you have a credit card

1015
00:52:30,030 --> 00:52:27,250
and you look at this thickness from

1016
00:52:33,330 --> 00:52:30,040
about a football field away that is

1017
00:52:35,730 --> 00:52:33,340
about one second of Arc so if you were

1018
00:52:38,750 --> 00:52:35,740
in a football field away and my credit

1019
00:52:42,420 --> 00:52:38,760
card would be doing no barely moving

1020
00:52:48,030 --> 00:52:42,430
that is the movement that you get at a

1021
00:52:50,460 --> 00:52:48,040
star one parsec away but better than

1022
00:52:53,870 --> 00:52:50,470
talking is doing so now we're going to

1023
00:52:56,580 --> 00:52:53,880
do your own parallax measurement and for

1024
00:52:59,190 --> 00:52:56,590
the people online I apologize that this

1025
00:53:02,730 --> 00:52:59,200
will probably not work as well as it

1026
00:53:04,320 --> 00:53:02,740
does here in the audience but so now for

1027
00:53:09,030 --> 00:53:04,330
the beginning what I'd like you to do is

1028
00:53:12,090 --> 00:53:09,040
extend out your finger and pick any

1029
00:53:15,060 --> 00:53:12,100
number in the ruler cover that number

1030
00:53:17,550 --> 00:53:15,070
with your finger and then blink your

1031
00:53:23,580 --> 00:53:17,560
eyes look at it first with one eye and

1032
00:53:25,500 --> 00:53:23,590
then the other and you will see that the

1033
00:53:27,600 --> 00:53:25,510
position of your finger moves of course

1034
00:53:31,290 --> 00:53:27,610
your finger is not moving it is just

1035
00:53:33,510 --> 00:53:31,300
this line-of-sight thing now bring your

1036
00:53:38,220 --> 00:53:33,520
finger closer dude you know I put it on

1037
00:53:42,210 --> 00:53:38,230
your nose and do it again and you'll see

1038
00:53:44,010 --> 00:53:42,220

a much bigger movement well that is

1039
00:53:46,020 --> 00:53:44,020
basically how we measure distance to

1040
00:53:48,390 --> 00:53:46,030
stars there are other methods but they

1041
00:53:50,780 --> 00:53:48,400
are all calibrated based on this method

1042
00:54:00,240 --> 00:53:50,790
this is the only direct method

1043
00:54:04,290 --> 00:54:00,250
everything else uses this as the base so

1044
00:54:05,820 --> 00:54:04,300
of course if it was as easy as looking

1045
00:54:09,230 --> 00:54:05,830
at our finger you know like life would

1046
00:54:12,210 --> 00:54:09,240
be easy it turns out that this effect is

1047
00:54:14,250 --> 00:54:12,220
right at the edge of what we can measure

1048
00:54:18,570 --> 00:54:14,260
with telescopes parallax is worth

1049
00:54:20,730 --> 00:54:18,580
measuring our you know extremely small

1050
00:54:23,960 --> 00:54:20,740
and convolved with many

1051
00:54:27,510 --> 00:54:23,970
optical factors you need very good

1052
00:54:30,330 --> 00:54:27,520
cameras to do this so this is me

1053
00:54:33,180 --> 00:54:30,340
measuring a parallax remotely this is my

1054
00:54:35,880 --> 00:54:33,190
office and Washington DC when I was a

1055
00:54:40,920 --> 00:54:35,890
postdoc this is the telescope in Chile

1056
00:54:46,890 --> 00:54:40,930
and what you see on the bottom left

1057
00:54:50,330 --> 00:54:46,900
image there this gold bottle here Dewar

1058
00:54:52,920 --> 00:54:50,340
is actually the instrument the camera

1059
00:54:55,740 --> 00:54:52,930
austra nominal cameras work with very

1060
00:54:58,560 --> 00:54:55,750
cold temperatures that increases their

1061
00:55:02,220 --> 00:54:58,570
conductivity and reduces noise so they

1062
00:55:07,109 --> 00:55:02,230
all work in in doers or bottles filled

1063
00:55:08,880 --> 00:55:07,119

with liquid nitrogen so and in Chile

1064
00:55:10,980 --> 00:55:08,890
there be a telescope operator an

1065
00:55:12,750 --> 00:55:10,990
engineer that is communicating with me

1066
00:55:14,730 --> 00:55:12,760
through Skype and is moving the

1067
00:55:18,720 --> 00:55:14,740
telescope and I have the camera controls

1068
00:55:23,070 --> 00:55:18,730
through the internet and so one of these

1069
00:55:25,290 --> 00:55:23,080
stars here is that one I'm trying to

1070
00:55:27,120 --> 00:55:25,300
measure the parallax for and all the

1071
00:55:31,260 --> 00:55:27,130
other ones are the reference stars they

1072
00:55:35,420 --> 00:55:31,270
are the background stars that are going

1073
00:55:38,280 --> 00:55:35,430
to be the numbers in in the ruler there

1074
00:55:42,120 --> 00:55:38,290
all right I see we're going low so I'm

1075
00:55:46,859 --> 00:55:42,130
going to skip a few so what are the

1076
00:55:50,250 --> 00:55:46,869
results once I put the parallax together

1077
00:55:52,200 --> 00:55:50,260
I mentioned that between this light and

1078
00:55:54,300 --> 00:55:52,210
the previous light a PhD thesis occurred

1079
00:55:56,070 --> 00:55:54,310
that's because I don't actually want to

1080
00:55:59,340 --> 00:55:56,080
bother you with all the mathematics of

1081
00:56:06,650 --> 00:55:59,350
how we go from those observations to

1082
00:56:12,230 --> 00:56:10,519
this is the new HR diagram that I made

1083
00:56:15,650 --> 00:56:12,240
as a result of my cases everything we're

1084
00:56:17,779 --> 00:56:15,660
seeing there is here in the last box so

1085
00:56:22,309 --> 00:56:17,789
there used to be about three stars there

1086
00:56:24,200 --> 00:56:22,319
and put a lot more will remember my

1087
00:56:25,849 --> 00:56:24,210
adviser had told me like put stars in

1088
00:56:32,150 --> 00:56:25,859

the HR diagram and a pattern rule comes

1089
00:56:33,799 --> 00:56:32,160
out I don't see no pattern I mean it it

1090
00:56:36,890 --> 00:56:33,809
doesn't look much better to me as it

1091
00:56:39,769 --> 00:56:36,900
does to you it is kind of it is kind of

1092
00:56:44,120 --> 00:56:39,779
a blob that is because we're looking at

1093
00:56:46,700 --> 00:56:44,130
it in in using the wrong variables it

1094
00:56:51,549 --> 00:56:46,710
turns out the HR diagram is also a tool

1095
00:56:54,799 --> 00:56:51,559
they'll tell you the radius of stars

1096
00:56:57,680 --> 00:56:54,809
these perpendicular lines here or the

1097
00:57:01,700 --> 00:56:57,690
slanted lines are actually radius lines

1098
00:57:05,089 --> 00:57:01,710
lines of constant radius so I'm going to

1099
00:57:07,759 --> 00:57:05,099
shift the axis here and now we have a

1100
00:57:10,970 --> 00:57:07,769
diagram that is in units of luminosity

1101
00:57:14,589 --> 00:57:10,980
so how bright object over here or

1102
00:57:19,190 --> 00:57:14,599
brighter then over there and radius

1103
00:57:20,960 --> 00:57:19,200
smaller and bigger and I'm just gonna

1104
00:57:24,440 --> 00:57:20,970
let you stare at that for a few seconds

1105
00:57:34,190 --> 00:57:24,450
and and and see if you can figure out

1106
00:57:42,570 --> 00:57:37,980
so what I'm seeing is that we have a

1107
00:57:45,900 --> 00:57:42,580
sequence that is coming down that is the

1108
00:57:52,980 --> 00:57:45,910
main sequence we talked about and then

1109
00:57:57,090 --> 00:57:52,990
we reach a minimum radius at that point

1110
00:58:03,030 --> 00:57:57,100
there and then we jump back to cooler or

1111
00:58:06,870 --> 00:58:03,040
fainter objects the higher radii let's

1112
00:58:11,060 --> 00:58:06,880
go back to the toy star here we

1113
00:58:14,160 --> 00:58:11,070

mentioned earlier that a star is fully

1114
00:58:17,790 --> 00:58:14,170
compressed it will ignite nuclear fusion

1115
00:58:20,160 --> 00:58:17,800
and it will have a source of energy and

1116
00:58:23,220 --> 00:58:20,170
therefore even as a fully compressed

1117
00:58:26,790 --> 00:58:23,230
star it will be able to survive as a

1118
00:58:29,190 --> 00:58:26,800
star for Brown doors in order to

1119
00:58:32,730 --> 00:58:29,200
generate energy they need to be in the

1120
00:58:35,940 --> 00:58:32,740
compression phase they need to be coming

1121
00:58:38,190 --> 00:58:35,950
down once they start contracting there

1122
00:58:41,910 --> 00:58:38,200
their energy generation stops and they

1123
00:58:44,850 --> 00:58:41,920
go down so the interpretation that we

1124
00:58:48,510 --> 00:58:44,860
did here is that these are fully

1125
00:58:51,960 --> 00:58:48,520
contracted stars and these are the brown

1126
00:58:54,090 --> 00:58:51,970
dwarfs because there are still shining

1127
00:58:55,950 --> 00:58:54,100
because they are in the process of

1128
00:58:57,900 --> 00:58:55,960
contraction because they haven't

1129
00:59:00,750 --> 00:58:57,910
finished their constructions they're

1130
00:59:03,090 --> 00:59:00,760
bigger they are a little bigger in

1131
00:59:07,020 --> 00:59:03,100
radius than the stars that is something

1132
00:59:10,670 --> 00:59:07,030
that theory predicts so we were able to

1133
00:59:14,730 --> 00:59:10,680
pinpoint that star to mass so 5 2 3

1134
00:59:17,760 --> 00:59:14,740
should be a minus minus 1403 as the

1135
00:59:24,150 --> 00:59:17,770
smallest star that we know of the end of

1136
00:59:28,650 --> 00:59:24,160
the main sequence and here's an image of

1137
00:59:32,070 --> 00:59:28,660
that it is serendipitously almost

1138
00:59:34,110 --> 00:59:32,080

exactly the size of Saturn so imagine

1139
00:59:37,200 --> 00:59:34,120
you know stars are such diverse objects

1140
00:59:40,830 --> 00:59:37,210
that you can get stars of planetary size

1141
00:59:44,730 --> 00:59:40,840
you know not Jupiter but Saturn which is

1142
00:59:45,840 --> 00:59:44,740
slightly smaller than Jupiter not mass

1143
00:59:48,890 --> 00:59:45,850
and density mass

1144
00:59:52,620 --> 00:59:48,900
city are much much higher than planets

1145
00:59:56,220 --> 00:59:52,630
it's luminosity it's about one egg

1146
01:00:00,270 --> 00:59:56,230
thousands of that of the Sun so you know

1147
01:00:03,510 --> 01:00:00,280
very very faint and if you're an amateur

1148
01:00:05,160 --> 01:00:03,520
astronomer you could find it in in Lepus

1149
01:00:08,370 --> 01:00:05,170
right under Araya

1150
01:00:10,380 --> 01:00:08,380
now this image here has a funny story

1151
01:00:12,480 --> 01:00:10,390
when when this paper came out I got a

1152
01:00:14,280 --> 01:00:12,490
call from sky and telescope they're like

1153
01:00:17,130 --> 01:00:14,290
we really would like to see the image of

1154
01:00:19,290 --> 01:00:17,140
this star it's like oh sure no problem

1155
01:00:21,740 --> 01:00:19,300
send me your email email them to the

1156
01:00:24,330 --> 01:00:21,750
discovery image from the telescope and

1157
01:00:27,870 --> 01:00:24,340
then the robot no we meant a color image

1158
01:00:29,520 --> 01:00:27,880
do you have a color image so I know that

1159
01:00:31,610 --> 01:00:29,530
that's not what we do like we don't work

1160
01:00:35,310 --> 01:00:31,620
in colors don't don't have a color image

1161
01:00:36,630 --> 01:00:35,320
what we really want a color image okay

1162
01:00:39,930 --> 01:00:36,640
well let me see what I can do

1163
01:00:42,900 --> 01:00:39,940

so the criteria for making this image is

1164
01:00:47,220 --> 01:00:42,910
that no matter how I played with the RGB

1165
01:00:49,440 --> 01:00:47,230
values the sky had to remain dark and so

1166
01:00:52,710 --> 01:00:49,450
that's how this image came about it is a

1167
01:00:55,590 --> 01:00:52,720
fake color image but you see the star is

1168
01:00:58,770 --> 01:00:55,600
a little redder as we expect it to be

1169
01:01:11,130 --> 01:00:58,780
and the sky is not some funny purple

1170
01:01:13,470 --> 01:01:11,140
color that came out so okay so I will

1171
01:01:16,530 --> 01:01:13,480
skip a little since we're late into how

1172
01:01:19,470 --> 01:01:16,540
we actually measure masses for these

1173
01:01:22,950 --> 01:01:19,480
stars it turns out that masses can only

1174
01:01:26,640 --> 01:01:22,960
be measured if you have two stars in a

1175
01:01:29,490 --> 01:01:26,650
binary system gravitational attraction

1176
01:01:34,320 --> 01:01:29,500
is a function of mass and it's really

1177
01:01:37,860 --> 01:01:34,330
the only way to tell you know how

1178
01:01:40,590 --> 01:01:37,870
massive the stars actually are so one of

1179
01:01:43,020 --> 01:01:40,600
the predictions that we made with that

1180
01:01:46,590 --> 01:01:43,030
star is that That star turned out to be

1181
01:01:49,110 --> 01:01:46,600
much cooler than colder and temperature

1182
01:01:53,510 --> 01:01:49,120
then what some of the models were

1183
01:01:56,760 --> 01:01:53,520
predicting for very low mass stars and

1184
01:01:58,960 --> 01:01:56,770
so we made a prediction that if we were

1185
01:02:01,000 --> 01:01:58,970
to find the mass

1186
01:02:04,030 --> 01:02:01,010
difference between stars and brown doors

1187
01:02:08,790 --> 01:02:04,040
it should also be different than what

1188
01:02:13,030 --> 01:02:08,800

the mass that the models were predicting

1189
01:02:16,750 --> 01:02:13,040
so we found the star called epsilon and

1190
01:02:20,260 --> 01:02:16,760
E was a binary system and we met heard

1191
01:02:25,839 --> 01:02:20,270
its orbit with again ground-based tools

1192
01:02:32,500 --> 01:02:25,849
and then when we combined the orbit the

1193
01:02:37,870 --> 01:02:32,510
theoretical Warbeck to the image we were

1194
01:02:42,099 --> 01:02:37,880
able to get masses and the mass that we

1195
01:02:45,010 --> 01:02:42,109
got was a mass of 75 jouvert masses for

1196
01:02:47,319 --> 01:02:45,020
brown dwarfs when models were saying

1197
01:02:51,579 --> 01:02:47,329
that those masses should be anywhere

1198
01:02:54,520 --> 01:02:51,589
from 73 to from 70 to 73 Jupiter masses

1199
01:02:56,770 --> 01:02:54,530
so this is the discrepancy between

1200
01:02:59,920 --> 01:02:56,780
models and theory that we were

1201
01:03:02,380 --> 01:02:59,930
investigating and it's a challenge for

1202
01:03:05,730 --> 01:03:02,390
the formation scenarios and for the

1203
01:03:08,740 --> 01:03:05,740
cooling scenarios for brown dwarfs and

1204
01:03:11,200 --> 01:03:08,750
how we're still investigating why that

1205
01:03:14,319 --> 01:03:11,210
is and why is it that we don't really

1206
01:03:17,290 --> 01:03:14,329
understand brown dwarf evolution at this

1207
01:03:19,240 --> 01:03:17,300
point and why is it that when you know

1208
01:03:22,420 --> 01:03:19,250
models are telling us Brown doors should

1209
01:03:23,980 --> 01:03:22,430
be one temperature observations are

1210
01:03:26,970 --> 01:03:23,990
telling us a different temperature and a

1211
01:03:31,150 --> 01:03:26,980
different mass so that is an ongoing

1212
01:03:33,700 --> 01:03:31,160
area of study here and more on that but

1213
01:03:37,839 --> 01:03:33,710

I'm actually not going to show you

1214
01:03:42,520 --> 01:03:37,849
because we have another movie this is a

1215
01:03:45,460 --> 01:03:42,530
movie of all stars within about a

1216
01:03:51,370 --> 01:03:45,470
hundred solar year a hundred light years

1217
01:03:53,530 --> 01:03:51,380
or so from us it is made by friend of

1218
01:03:58,180 --> 01:03:53,540
mine who also works here called addre

1219
01:04:02,589 --> 01:03:58,190
credo and he is an artist at computer

1220
01:04:04,900 --> 01:04:02,599
graphics so what we'll see here is an

1221
01:04:10,320 --> 01:04:04,910
animation going out from the Sun looking

1222
01:04:21,019 --> 01:04:12,210
[Music]

1223
01:04:21,029 --> 01:04:27,320
you

1224
01:04:27,330 --> 01:04:45,860
this

1225
01:04:45,870 --> 01:04:49,250
you

1226
01:06:21,890 --> 01:05:20,430
[Music]

1227
01:07:02,440 --> 01:06:54,930
[Applause]

1228
01:07:02,450 --> 01:07:09,110
[Music]

1229
01:07:09,120 --> 01:07:35,940
[Applause]

1230
01:08:35,620 --> 01:07:43,080
[Music]

1231
01:08:41,060 --> 01:08:39,440
so none of that is my credit Adric Guido

1232
01:08:44,000 --> 01:08:41,070
who's a software engineer in this

1233
01:08:46,640 --> 01:08:44,010
building did this one he was in graduate

1234
01:08:54,079 --> 01:08:46,650
school and no we don't want to see the

1235
01:09:06,530 --> 01:08:54,089
next YouTube video I'll put this back up

1236
01:09:09,620 --> 01:09:06,540
I guess the next video okay so

1237
01:09:12,820 --> 01:09:09,630
conclusions we know where the brown

1238
01:09:15,860 --> 01:09:12,830

dwarfs are and where the slow is the

1239
01:09:19,099 --> 01:09:15,870
least massive stars are right now we've

1240
01:09:21,349 --> 01:09:19,109
been pointed one star and we stayed that

1241
01:09:24,140 --> 01:09:21,359
is the least massive and smallest star

1242
01:09:28,640 --> 01:09:24,150
that we know of we are still studying

1243
01:09:33,329 --> 01:09:28,650
them as a population is that my music

1244
01:09:33,339 --> 01:09:44,920
I see okay sorry

1245
01:09:51,840 --> 01:09:47,750
[Music]

1246
01:09:56,770 --> 01:09:51,850
okay there we go one last thing I wanted

1247
01:09:56,780 --> 01:10:04,209
over

1248
01:10:08,180 --> 01:10:06,530
so the rules are that you are not

1249
01:10:10,339 --> 01:10:08,190
allowed to do any of this work in

1250
01:10:14,209 --> 01:10:10,349
astronomy unless you have a church that

1251
01:10:16,640 --> 01:10:14,219
says you're thinking about it and so

1252
01:10:19,430 --> 01:10:16,650
should you like to buy the church here

1253
01:10:22,370 --> 01:10:19,440
is the link on my website and you can

1254
01:10:26,120 --> 01:10:22,380
buy it on cost from the company that did

1255
01:10:27,890 --> 01:10:26,130
this so this will be in and that there

1256
01:10:31,399 --> 01:10:27,900
are stars on the back to prove that it's

1257
01:10:33,350 --> 01:10:31,409
about stars really yeah so that's all I

1258
01:10:42,689 --> 01:10:33,360
had I'm sorry I went over a little thank

1259
01:10:51,450 --> 01:10:49,870
Weston yes so I noticed on one of the

1260
01:10:54,700 --> 01:10:51,460
last screens it was talking about

1261
01:10:58,509 --> 01:10:54,710
singles binary triples and right while

1262
01:11:00,100 --> 01:10:58,519
it wasn't our the low mass stars do they

1263
01:11:01,959 --> 01:11:00,110

hang out with other little monsters or

1264
01:11:05,709 --> 01:11:01,969
there's likely to be with any other way

1265
01:11:09,970 --> 01:11:05,719
very good question and the answer is

1266
01:11:13,509 --> 01:11:09,980
that as you go down in mass the tendency

1267
01:11:15,220 --> 01:11:13,519
to be binaries decreases so for the very

1268
01:11:18,189 --> 01:11:15,230
high mass stars there are eventually all

1269
01:11:20,950 --> 01:11:18,199
binaries when you get to the very low

1270
01:11:23,200 --> 01:11:20,960
mass stars there is about 30% binary key

1271
01:11:30,790 --> 01:11:23,210
and when we get to the brown dwarfs it's

1272
01:11:33,520 --> 01:11:30,800
only 20% I heard somewhere that the

1273
01:11:35,049 --> 01:11:33,530
brown dwarfs will last for a trillion

1274
01:11:36,669 --> 01:11:35,059
years that they won't burn out because

1275
01:11:40,810 --> 01:11:36,679
they have formed some sort of

1276
01:11:45,160 --> 01:11:40,820
equilibrium is that true so that is true

1277
01:11:46,959 --> 01:11:45,170
for the very low mass stars not the

1278
01:11:49,450 --> 01:11:46,969
brown dwarfs is that a very interesting

1279
01:11:51,450 --> 01:11:49,460
point that for very low mass stars one

1280
01:11:54,310 --> 01:11:51,460
you reach that equilibrium phase

1281
01:11:57,729 --> 01:11:54,320
predicted to last longer than the

1282
01:12:01,479 --> 01:11:57,739
current age of the universe so no low

1283
01:12:05,140 --> 01:12:01,489
mass star no M dwarf has yet evolved to

1284
01:12:07,569 --> 01:12:05,150
its adult - to its old age they're all

1285
01:12:10,410 --> 01:12:07,579
stubble dotes now for brown dwarfs there

1286
01:12:13,540 --> 01:12:10,420
will be continuously cooling down so

1287
01:12:15,700 --> 01:12:13,550
brown dwarfs don't have stability that

1288
01:12:17,109 --> 01:12:15,710

was a question that came up online so

1289
01:12:18,790 --> 01:12:17,119
brown dwarfs shine while they're

1290
01:12:20,979 --> 01:12:18,800
contracting how long does that

1291
01:12:23,520 --> 01:12:20,989
contracting phase last do we have a good

1292
01:12:28,629 --> 01:12:23,530
estimate of how long they will shine

1293
01:12:30,279 --> 01:12:28,639
right so it depends on the yesterday

1294
01:12:32,140 --> 01:12:30,289
that question depends on how powerful

1295
01:12:37,569 --> 01:12:32,150
your telescope is and what you consider

1296
01:12:39,220 --> 01:12:37,579
shine to be in this phase where they are

1297
01:12:44,080 --> 01:12:39,230
shining so bright that they're being

1298
01:12:46,979 --> 01:12:44,090
confused with stars that is about the

1299
01:12:51,819 --> 01:12:46,989
first one and a half billion with a B

1300
01:12:52,600 --> 01:12:51,829
Giga years for brown dwarfs the real

1301
01:12:55,479 --> 01:12:52,610
zone

1302
01:12:57,750 --> 01:12:55,489
of confusion is about 600 million years

1303
01:13:01,930 --> 01:12:57,760
once you get to several billion years

1304
01:13:04,419 --> 01:13:01,940
they get very cold and undetectable

1305
01:13:06,490 --> 01:13:04,429
well my follow-up question would be this

1306
01:13:08,169 --> 01:13:06,500
gives a the low mass stars where life

1307
01:13:11,410 --> 01:13:08,179
can evolve around them because they last

1308
01:13:13,359 --> 01:13:11,420
so long to planetary systems would be

1309
01:13:17,590 --> 01:13:13,369
stable enough for life to evolve is that

1310
01:13:22,570 --> 01:13:17,600
correct well there's a million-dollar

1311
01:13:24,879 --> 01:13:22,580
question and there are two camps - - the

1312
01:13:29,189 --> 01:13:24,889
the one camp is exactly what you said

1313
01:13:31,479 --> 01:13:29,199

that you know that they are very good

1314
01:13:34,330 --> 01:13:31,489
candidates for life because of their

1315
01:13:38,379 --> 01:13:34,340
stability they also do tend to harbor

1316
01:13:41,379 --> 01:13:38,389
rocky planets we know that the flip side

1317
01:13:43,660 --> 01:13:41,389
of the coin is that these stars are not

1318
01:13:46,750 --> 01:13:43,670
very far metrically stable they tend to

1319
01:13:48,939 --> 01:13:46,760
flare a lot and they tend to emit a lot

1320
01:13:51,790 --> 01:13:48,949
of x-rays and UV radiation when they

1321
01:13:53,830 --> 01:13:51,800
flare and because they are so faint a

1322
01:13:56,590 --> 01:13:53,840
planet in the so-called habitable zone

1323
01:13:58,870 --> 01:13:56,600
would have to be very very close to the

1324
01:14:00,729 --> 01:13:58,880
star for it to be warm enough so we

1325
01:14:03,310 --> 01:14:00,739
would be very susceptible to those

1326
01:14:04,959 --> 01:14:03,320
players that is actually an active line

1327
01:14:07,229 --> 01:14:04,969
of research for me right now I'm trying

1328
01:14:09,459 --> 01:14:07,239
to understand their flaring rates by

1329
01:14:11,770 --> 01:14:09,469
trying to get a handle on their spot

1330
01:14:16,530 --> 01:14:11,780
patterns are they very spotted or are

1331
01:14:25,050 --> 01:14:22,379
good how does the fusion of deuterium

1332
01:14:27,280 --> 01:14:25,060
factor into the life of a brown dwarf

1333
01:14:30,490 --> 01:14:27,290
that is an excellent question

1334
01:14:33,220 --> 01:14:30,500
brown dwarfs are objects that can fuse

1335
01:14:35,320 --> 01:14:33,230
the terrarium but can you not fuse light

1336
01:14:36,700 --> 01:14:35,330
hydrogen yeah you'd make sure people

1337
01:14:40,180 --> 01:14:36,710
know what deuterium is right right so

1338
01:14:43,359 --> 01:14:40,190

deuterium is sometimes called heavy

1339
01:14:46,300 --> 01:14:43,369
hydrogen it is a hydrogen has a nucleus

1340
01:14:50,229 --> 01:14:46,310
that's just one proton a deuterium or

1341
01:14:53,350 --> 01:14:50,239
hydrogen - has a proton and then a

1342
01:14:56,879 --> 01:14:53,360
neutron right next to it so it is twice

1343
01:14:59,740 --> 01:14:56,889
as heavy and that extra Neutron

1344
01:15:02,130 --> 01:14:59,750
intermediate the fusion process and

1345
01:15:04,050 --> 01:15:02,140
makes fusion much easier -

1346
01:15:05,550 --> 01:15:04,060
to happen right so deuterium fusion

1347
01:15:07,440 --> 01:15:05,560
happens at a lower temperature than

1348
01:15:08,850 --> 01:15:07,450
hydrogen fusion sure in fusion happens

1349
01:15:12,990 --> 01:15:08,860
there at a much lower temperature and

1350
01:15:16,560 --> 01:15:13,000
brown dwarfs can burn deuterium yes but

1351
01:15:19,020 --> 01:15:16,570
the the thing is that there's so little

1352
01:15:21,780 --> 01:15:19,030
deuterium compared to hydrogen to begin

1353
01:15:23,520 --> 01:15:21,790
with that that bursts that they get from

1354
01:15:26,070 --> 01:15:23,530
the deuterium burning called the

1355
01:15:28,500 --> 01:15:26,080
determining sequence is very short-lived

1356
01:15:36,630 --> 01:15:28,510
than not very consequential for the

1357
01:15:39,660 --> 01:15:36,640
evolution the object if you said it and

1358
01:15:43,140 --> 01:15:39,670
I didn't get it I apologize the question

1359
01:15:45,060 --> 01:15:43,150
is what led you to find that little star

1360
01:15:47,310 --> 01:15:45,070
that you showed us on the screen out of

1361
01:15:49,560 --> 01:15:47,320
all the stars and all the gas and all

1362
01:15:56,160 --> 01:15:49,570
the things you can smell all the gin

1363
01:15:58,290 --> 01:15:56,170

joints you can walk you know that that

1364
01:16:01,200 --> 01:15:58,300
is a really important question because

1365
01:16:07,410 --> 01:16:01,210
there are more stars out there than we

1366
01:16:10,170 --> 01:16:07,420
can possibly study you know so one of

1367
01:16:11,040 --> 01:16:10,180
the arts in astronomy is really sample

1368
01:16:13,890 --> 01:16:11,050
formation

1369
01:16:16,230 --> 01:16:13,900
you know what sample of stars are you

1370
01:16:19,110 --> 01:16:16,240
going to study how are you going to

1371
01:16:21,240 --> 01:16:19,120
design your sample so that it is

1372
01:16:23,790 --> 01:16:21,250
unbiased and so that it's going to be

1373
01:16:24,930 --> 01:16:23,800
representative you can think of polling

1374
01:16:27,990 --> 01:16:24,940
you know like there are those people

1375
01:16:31,710 --> 01:16:28,000
that do electro polls and and and get it

1376
01:16:33,750 --> 01:16:31,720
smack on it is a functional sample

1377
01:16:36,930 --> 01:16:33,760
design how they're designing the sample

1378
01:16:41,430 --> 01:16:36,940
that you're doing in this case what we

1379
01:16:43,680 --> 01:16:41,440
did is we picked known stars that we

1380
01:16:45,750 --> 01:16:43,690
thought would be around that temperature

1381
01:16:48,450 --> 01:16:45,760
range so that we thought would be on

1382
01:16:50,610 --> 01:16:48,460
either side of the boundary and we said

1383
01:16:52,920 --> 01:16:50,620
let's extrapolate enough to both sides

1384
01:16:55,410 --> 01:16:52,930
that we know that we'll have a

1385
01:16:57,270 --> 01:16:55,420
representative sample what does not

1386
01:17:02,010 --> 01:16:57,280
factor into our sample is there

1387
01:17:02,700 --> 01:17:02,020
abundance so we just SPECT basically one

1388
01:17:04,620 --> 01:17:02,710

of each color

1389
01:17:07,680 --> 01:17:04,630
we don't doesn't care about the fact

1390
01:17:09,750 --> 01:17:07,690
that a certain type has many more stars

1391
01:17:11,250 --> 01:17:09,760
than than the other that what I'm

1392
01:17:13,980 --> 01:17:11,260
describing now called the volume

1393
01:17:15,840 --> 01:17:13,990
complete sample is something we're doing

1394
01:17:16,950 --> 01:17:15,850
only now

1395
01:17:19,440 --> 01:17:16,960
okay so we had a question similar

1396
01:17:23,460 --> 01:17:19,450
related to that you showed very clearly

1397
01:17:26,190 --> 01:17:23,470
that the minimum size of a star is about

1398
01:17:27,960 --> 01:17:26,200
9% of the size of the Sun right but it

1399
01:17:30,540 --> 01:17:27,970
wasn't obvious from your graphs what the

1400
01:17:32,040 --> 01:17:30,550
mass of that object would be and I

1401
01:17:35,430 --> 01:17:32,050
assumed it was like 70 Jupiter masses

1402
01:17:39,840 --> 01:17:35,440
but is that is that was that correct

1403
01:17:42,510 --> 01:17:39,850
so yes the number we got and and I

1404
01:17:44,700 --> 01:17:42,520
actually did skim very quickly through

1405
01:17:46,710 --> 01:17:44,710
this because we were running a long time

1406
01:17:49,890 --> 01:17:46,720
but the number the models are indicating

1407
01:17:52,200 --> 01:17:49,900
are close to 70 Jupiter masses we're

1408
01:17:54,630 --> 01:17:52,210
getting numbers closer to 75 Juber

1409
01:17:56,070 --> 01:17:54,640
masses so what does that in solar masses

1410
01:17:57,270 --> 01:17:56,080
because I didn't I didn't have that in

1411
01:17:59,960 --> 01:17:57,280
my head uh-huh

1412
01:18:04,230 --> 01:17:59,970
this is actually a very convenient

1413
01:18:07,410 --> 01:18:04,240

conversion just add two zeros 0.07

1414
01:18:11,820 --> 01:18:07,420
that's what I remember is about one 1000

1415
01:18:14,880 --> 01:18:11,830
the mass of the Sun good I think my

1416
01:18:17,100 --> 01:18:14,890
question guy answered my question was

1417
01:18:19,680 --> 01:18:17,110
what would it take for Jupiter to become

1418
01:18:23,610 --> 01:18:19,690
a brown dwarf why is it not a brown dog

1419
01:18:25,620 --> 01:18:23,620
right so there are actually two ways

1420
01:18:29,160 --> 01:18:25,630
that we define brown dwarfs on the lower

1421
01:18:31,080 --> 01:18:29,170
limit one way is the question we had

1422
01:18:34,530 --> 01:18:31,090
earlier whether it burns deuterium or

1423
01:18:36,870 --> 01:18:34,540
not and that definition the models Frodo

1424
01:18:40,140 --> 01:18:36,880
take about 13 times the size of Jupiter

1425
01:18:43,770 --> 01:18:40,150
so an object of 13 Jupiter masses would

1426
01:18:46,290 --> 01:18:43,780
be round or the other definition which I

1427
01:18:49,110 --> 01:18:46,300
think is is is being more favoured by

1428
01:18:51,810 --> 01:18:49,120
the community now has to do with whether

1429
01:18:54,600 --> 01:18:51,820
it formed as a planet or whether it

1430
01:18:56,640 --> 01:18:54,610
formed as a star if something forms in a

1431
01:19:00,180 --> 01:18:56,650
circumstellar disk and is a you know

1432
01:19:02,100 --> 01:19:00,190
leftover from stellar formation then it

1433
01:19:05,280 --> 01:19:02,110
would be considered a planet regardless

1434
01:19:08,040 --> 01:19:05,290
of its mass and if it formed like we saw

1435
01:19:11,040 --> 01:19:08,050
in that first slide when you know by

1436
01:19:12,750 --> 01:19:11,050
cloud collapse then it would be

1437
01:19:22,490 --> 01:19:12,760
considered a brown dwarf regardless of

1438
01:19:29,069 --> 01:19:27,209

hello just a quick one um how much is

1439
01:19:32,459 --> 01:19:29,079
the Webb telescope going to help you on

1440
01:19:35,279 --> 01:19:32,469
this it is going to help substantially

1441
01:19:39,169 --> 01:19:35,289
because it is an infrared telescope and

1442
01:19:42,390 --> 01:19:39,179
all this is being done in the infrared

1443
01:19:44,310 --> 01:19:42,400
one of the projects which I'm going to

1444
01:19:48,479 --> 01:19:44,320
propose to do and I'm really excited

1445
01:19:51,229 --> 01:19:48,489
about is that these objects have a lot

1446
01:19:54,089 --> 01:19:51,239
of water vapour in their atmosphere and

1447
01:19:55,859 --> 01:19:54,099
from Earth we have water vapor in our

1448
01:19:58,560 --> 01:19:55,869
atmosphere so from a ground-based

1449
01:20:02,250 --> 01:19:58,570
telescope it becomes very difficult to

1450
01:20:04,290 --> 01:20:02,260
deconvolve the two signals haveö cannot

1451
01:20:08,010 --> 01:20:04,300
reach that far into the infrared to do

1452
01:20:12,540 --> 01:20:08,020
it but Webb is going to do it so I hope

1453
01:20:14,189 --> 01:20:12,550
to get a time yes mm-hmm and as far as

1454
01:20:15,779 --> 01:20:14,199
the sensitivity goes it's not going to

1455
01:20:17,370 --> 01:20:15,789
be an issue for Webb at all I mean it

1456
01:20:20,189 --> 01:20:17,380
isn't for about these are powerful

1457
01:20:23,549 --> 01:20:20,199
telescopes so really any question is w

1458
01:20:25,979 --> 01:20:23,559
first with its you know incredible field

1459
01:20:27,149 --> 01:20:25,989
of view and hubble Senate Hubble

1460
01:20:29,010 --> 01:20:27,159
resolution is it going to go far enough

1461
01:20:33,689 --> 01:20:29,020
in their infrared to really do much on

1462
01:20:35,189 --> 01:20:33,699
stellar yes so this is a really

1463
01:20:37,799 --> 01:20:35,199

interesting and we actually made a case

1464
01:20:41,339 --> 01:20:37,809
for w first for this is that this

1465
01:20:44,729 --> 01:20:41,349
smaller star that I showed here was 10

1466
01:20:47,910 --> 01:20:44,739
parsecs away or there abouts I think it

1467
01:20:51,089 --> 01:20:47,920
was 12 parsecs w first would be able to

1468
01:20:54,330 --> 01:20:51,099
pick up that star in a crowded field in

1469
01:20:56,040 --> 01:20:54,340
a full quadrant of the galaxy so we're

1470
01:20:59,189 --> 01:20:56,050
talking about one one thousandth of the

1471
01:21:01,589 --> 01:20:59,199
galaxy that we first would be able to do

1472
01:21:04,319 --> 01:21:01,599
you know a fourth of the galaxy in

1473
01:21:06,990 --> 01:21:04,329
survey mode it wouldn't even have to be

1474
01:21:08,819 --> 01:21:07,000
pointed observations so would be a very

1475
01:21:11,069 --> 01:21:08,829
powerful tool for this yeah if you don't

1476
01:21:13,490 --> 01:21:11,079
know W first has you know what three

1477
01:21:16,410 --> 01:21:13,500
hundred million pixels per observation

1478
01:21:18,149 --> 01:21:16,420
but with Hubble resolution and it is an

1479
01:21:21,000 --> 01:21:18,159
infrared telescope but it's a survey

1480
01:21:24,149 --> 01:21:21,010
telescope so it's gonna it's gonna

1481
01:21:26,430 --> 01:21:24,159
increase the data rate high a very large

1482
01:21:28,470 --> 01:21:26,440
amount around here some of the time is

1483
01:21:31,680 --> 01:21:28,480
going to be dedicated for 4pi searches

1484
01:21:32,339 --> 01:21:31,690
yes as well so yeah alright one last

1485
01:21:34,650 --> 01:21:32,349
question

1486
01:21:36,460 --> 01:21:34,660
anybody got it

1487
01:21:38,740 --> 01:21:36,470
okay if we don't have a last question

1488
01:21:40,750 --> 01:21:38,750

let's hold on we're not gonna thank our

1489
01:21:43,000 --> 01:21:40,760
speaker just yet I have to remind you

1490
01:21:44,830 --> 01:21:43,010
that next month we will probably have

1491
01:21:46,570 --> 01:21:44,840
construction in the lobby look for the

1492
01:21:50,500 --> 01:21:46,580
signs to see where the entrance to the

1493
01:21:52,780 --> 01:21:50,510
building is second thing we're just 14th

1494
01:21:55,150 --> 01:21:52,790
the second Tuesday all right not the

1495
01:21:57,430 --> 01:21:55,160
first Tuesday the second Tuesday I'll be

1496
01:21:59,680 --> 01:21:57,440
in Hawaii and the first Tuesday you're

1497
01:22:01,390 --> 01:21:59,690
welcome to come join me there but that's

1498
01:22:04,480 --> 01:22:01,400
where the devil is meeting is and

1499
01:22:05,160 --> 01:22:04,490
finally let us thank Serge for a