PUBLIC LECTURE SERIES

Sailing across the Local Universe with ULLYSES

Featuring Guest Speaker :

Will Fischer

1
00:00:05,349 --> 00:00:03,110
welcome

2
00:00:06,389 --> 00:00:05,359
to the space telescope public lecture

3
00:00:09,270 --> 00:00:06,399
series

4
00:00:11,190 --> 00:00:09,280
today's talk sailing across the local

5
00:00:13,830 --> 00:00:11,200
universe with ulysses

6
00:00:15,430 --> 00:00:13,840
a hubble program to observe ultraviolet

7
00:00:19,349 --> 00:00:15,440
light from young stars

8
00:00:21,349 --> 00:00:19,359
presented by will fisher i am your host

9
00:00:23,590 --> 00:00:21,359
dr frank summers of the office of public

10
00:00:24,790 --> 00:00:23,600
outreach at the space telescope science

11
00:00:26,630 --> 00:00:24,800
institute

12
00:00:29,109 --> 00:00:26,640
i'd like to note that the space

13
00:00:30,790 --> 00:00:29,119

telescope public lecture series which

14
00:00:32,310 --> 00:00:30,800
previously had been done in the

15
00:00:34,950 --> 00:00:32,320
auditorium

16
00:00:36,630 --> 00:00:34,960
is now an online only series until

17
00:00:39,350 --> 00:00:36,640
further notice

18
00:00:40,630 --> 00:00:39,360
i also want to make great thanks to our

19
00:00:43,670 --> 00:00:40,640
amazing tech

20
00:00:46,310 --> 00:00:43,680
team thomas marufu and grant justice

21
00:00:50,630 --> 00:00:46,320
who've adapted to this online format in

22
00:00:56,630 --> 00:00:53,750
coming up next month we have on

23
00:00:57,510 --> 00:00:56,640
october 6th we have nancy grace roman

24
00:01:00,150 --> 00:00:57,520
and the roman

25
00:01:02,229 --> 00:01:00,160
space telescope we have two special

26
00:01:05,030 --> 00:01:02,239
speakers coming from nasa goddard

27
00:01:06,630 --> 00:01:05,040
space flight center jennifer wiseman and

28
00:01:08,630 --> 00:01:06,640
julie mcenery

29
00:01:10,789 --> 00:01:08,640
and this is this is really cool this is

30
00:01:11,429 --> 00:01:10,799
a brand new space telescope that will be

31
00:01:14,950 --> 00:01:11,439
launching

32
00:01:16,230 --> 00:01:14,960
this uh in the in this decade and it's

33
00:01:18,550 --> 00:01:16,240
yeah it's going to be it's going to be a

34
00:01:22,149 --> 00:01:18,560
fun stuff fun stuff to learn

35
00:01:24,789 --> 00:01:22,159
on november 10th we have astronomify

36
00:01:26,070 --> 00:01:24,799
sonification of astronomical data from

37
00:01:28,390 --> 00:01:26,080
scott fleming

38
00:01:30,390 --> 00:01:28,400

and this is a really cool program to

39
00:01:33,030 --> 00:01:30,400
take astronomy data

40
00:01:34,950 --> 00:01:33,040
and turn it into sounds and see what we

41
00:01:38,069 --> 00:01:34,960
can learn from that

42
00:01:39,429 --> 00:01:38,079
and then in december mitchell rovolsky

43
00:01:41,670 --> 00:01:39,439
will be talking about

44
00:01:42,870 --> 00:01:41,680
active galaxies now i actually i expect

45
00:01:44,630 --> 00:01:42,880
him to

46
00:01:46,630 --> 00:01:44,640
revise that title and give me something

47
00:01:47,190 --> 00:01:46,640
a little bit more but hey he's got three

48
00:01:49,350 --> 00:01:47,200
months

49
00:01:51,109 --> 00:01:49,360
he'll get to it where are you going to

50
00:01:54,230 --> 00:01:51,119
find out that information well you're

51
00:01:57,270 --> 00:01:54,240
going to go you can go to our website

52
00:02:00,230 --> 00:01:57,280
if you just go to sdsci.edu

53
00:02:03,030 --> 00:02:00,240
public hyphen lectures you'll find this

54
00:02:05,350 --> 00:02:03,040
webpage with all the information on it

55
00:02:07,109 --> 00:02:05,360
you can see on the left hand side uh the

56
00:02:09,749 --> 00:02:07,119
links to our webcast

57
00:02:11,910 --> 00:02:09,759
both the youtube playlist as well as the

58
00:02:13,510 --> 00:02:11,920
webcast archive at the space telescope

59
00:02:16,869 --> 00:02:13,520
science institute

60
00:02:17,750 --> 00:02:16,879
and on the right you can see the big red

61
00:02:20,150 --> 00:02:17,760
button

62
00:02:20,869 --> 00:02:20,160
that allows you to subscribe to our

63
00:02:26,070 --> 00:02:20,879

emails

64
00:02:29,030 --> 00:02:26,080
giving you notice of what's coming on

65
00:02:29,589 --> 00:02:29,040
each of the lectures has a link about it

66
00:02:32,229 --> 00:02:29,599
with the

67
00:02:33,430 --> 00:02:32,239
information and the abstract and a

68
00:02:37,030 --> 00:02:33,440
little bit more

69
00:02:37,750 --> 00:02:37,040
if you go to the the page for each

70
00:02:40,150 --> 00:02:37,760
lecture

71
00:02:42,309 --> 00:02:40,160
um then after it's recorded they have a

72
00:02:43,350 --> 00:02:42,319
link for the webcast on the sdi ci

73
00:02:45,830 --> 00:02:43,360
webcasting

74
00:02:48,390 --> 00:02:45,840
as well as down bottom the link for the

75
00:02:49,910 --> 00:02:48,400
youtube webcast

76
00:02:51,910 --> 00:02:49,920
if you would like to get reminders of

77
00:02:52,869 --> 00:02:51,920
all this well you can sign up for the

78
00:02:55,589 --> 00:02:52,879
announcements

79
00:02:58,229 --> 00:02:55,599
as i showed you at our website you can

80
00:03:01,350 --> 00:02:58,239
also subscribe to our youtube channel

81
00:03:02,390 --> 00:03:01,360
and uh which is youtube.com hubble space

82
00:03:04,390 --> 00:03:02,400
telescope

83
00:03:06,149 --> 00:03:04,400
and that will give you new video notices

84
00:03:08,470 --> 00:03:06,159
and reminders of live events

85
00:03:09,670 --> 00:03:08,480
so you get to hear about not just our

86
00:03:11,270 --> 00:03:09,680
public lecture series

87
00:03:14,229 --> 00:03:11,280
but also the other videos that we

88
00:03:16,309 --> 00:03:14,239

produce finally if you have comments or

89
00:03:20,630 --> 00:03:16,319
questions you can send them to public

90
00:03:22,790 --> 00:03:20,640
lecture at stsci.edu

91
00:03:24,869 --> 00:03:22,800
you might also want to follow our social

92
00:03:26,550 --> 00:03:24,879
media we have social media accounts for

93
00:03:29,190 --> 00:03:26,560
the hubble space telescope

94
00:03:31,270 --> 00:03:29,200
for the web space telescope and for the

95
00:03:33,910 --> 00:03:31,280
space telescope science institute

96
00:03:34,550 --> 00:03:33,920
on various media like facebook twitter

97
00:03:37,750 --> 00:03:34,560
youtube

98
00:03:38,470 --> 00:03:37,760
and instagram if you want to know what

99
00:03:41,350 --> 00:03:38,480
i'm thinking

100
00:03:42,229 --> 00:03:41,360
every now and then i post on facebook

101
00:03:44,789 --> 00:03:42,239
and twitter

102
00:03:46,070 --> 00:03:44,799
not an awful lot so guarantee you will

103
00:03:49,670 --> 00:03:46,080
not be inundated with

104
00:03:50,229 --> 00:03:49,680
my tweets however what you will hear

105
00:03:52,309 --> 00:03:50,239
from me

106
00:03:54,190 --> 00:03:52,319
is the news from the universe and this

107
00:03:56,229 --> 00:03:54,200
is the news from the earth for september

108
00:03:59,429 --> 00:03:56,239
2020

109
00:04:03,190 --> 00:03:59,439
our first story tonight studying

110
00:04:05,110 --> 00:04:03,200
extrasolar planets via the moon

111
00:04:06,789 --> 00:04:05,120
hmm i put a question mark there because

112
00:04:07,990 --> 00:04:06,799
that doesn't sound like that really

113
00:04:09,509 --> 00:04:08,000

makes any sense

114
00:04:11,670 --> 00:04:09,519
all right let's start with extrasolar

115
00:04:14,390 --> 00:04:11,680
planets here is an artist

116
00:04:14,869 --> 00:04:14,400
drawing of an extrasolar planet a planet

117
00:04:17,590 --> 00:04:14,879
around

118
00:04:19,189 --> 00:04:17,600
another star and we know of lots of

119
00:04:22,550 --> 00:04:19,199
these extrasolar planets about

120
00:04:23,670 --> 00:04:22,560
3 000 of them okay actually more like

121
00:04:26,550 --> 00:04:23,680
four thousand if i

122
00:04:28,150 --> 00:04:26,560
uh to correct myself and sometimes as

123
00:04:30,390 --> 00:04:28,160
you can see in this drawing

124
00:04:31,909 --> 00:04:30,400
an extrasolar planet will pass in front

125
00:04:34,629 --> 00:04:31,919
of its star

126
00:04:35,270 --> 00:04:34,639
and the light from that star will pass

127
00:04:38,390 --> 00:04:35,280
through the

128
00:04:40,790 --> 00:04:38,400
atmosphere of that extrasolar planet

129
00:04:41,590 --> 00:04:40,800
so what's really cool about extrasolar

130
00:04:44,710 --> 00:04:41,600
planets

131
00:04:47,189 --> 00:04:44,720
is we can actually see what's

132
00:04:48,390 --> 00:04:47,199
in the atmosphere of these extrasolar

133
00:04:51,430 --> 00:04:48,400
planets

134
00:04:53,030 --> 00:04:51,440
here for example is the spectrum of one

135
00:04:56,070 --> 00:04:53,040
extrasolar planet called

136
00:04:58,950 --> 00:04:56,080
hat p26b

137
00:04:59,510 --> 00:04:58,960
and the uh black dots are the actual

138
00:05:02,629 --> 00:04:59,520

data

139
00:05:03,510 --> 00:05:02,639
from half p 26 b and the red and blue

140
00:05:06,469 --> 00:05:03,520
lines those

141
00:05:07,510 --> 00:05:06,479
are a fit based upon what we expect to

142
00:05:10,550 --> 00:05:07,520
see

143
00:05:12,070 --> 00:05:10,560
of the graph

144
00:05:13,590 --> 00:05:12,080
that there's this big bump that

145
00:05:16,950 --> 00:05:13,600
definitely indicates

146
00:05:17,909 --> 00:05:16,960
a water emission line h2o water emission

147
00:05:20,629 --> 00:05:17,919
line

148
00:05:22,629 --> 00:05:20,639
but on the right side there could be a

149
00:05:23,670 --> 00:05:22,639
bump due to carbon dioxide or carbon

150
00:05:25,590 --> 00:05:23,680
monoxide

151
00:05:26,710 --> 00:05:25,600
that isn't really quite there in the

152
00:05:29,590 --> 00:05:26,720
data

153
00:05:30,550 --> 00:05:29,600
so we can see the various uh components

154
00:05:34,790 --> 00:05:30,560
and it's basically

155
00:05:37,110 --> 00:05:34,800
you know water methane carbon monoxide

156
00:05:38,070 --> 00:05:37,120
uh the basic chemicals that you expect

157
00:05:40,310 --> 00:05:38,080
to see we've seen

158
00:05:41,350 --> 00:05:40,320
all those in various planets we didn't

159
00:05:44,790 --> 00:05:41,360
see them all in half

160
00:05:47,510 --> 00:05:44,800
p 26b but in various planets but what we

161
00:05:48,550 --> 00:05:47,520
haven't seen and one of the interesting

162
00:05:51,670 --> 00:05:48,560
things that we

163
00:05:52,950 --> 00:05:51,680

want to see is something that we see on

164
00:05:58,790 --> 00:05:52,960
earth

165
00:06:00,150 --> 00:05:58,800
actually absorbs a lot of the

166
00:06:02,070 --> 00:06:00,160
ultraviolet light

167
00:06:03,749 --> 00:06:02,080
if it wasn't for the ozone layer the

168
00:06:04,230 --> 00:06:03,759
ultraviolet light that gets to the

169
00:06:07,189 --> 00:06:04,240
ground

170
00:06:08,950 --> 00:06:07,199
would be much greater you also may

171
00:06:11,670 --> 00:06:08,960
notice in this diagram that there

172
00:06:13,270 --> 00:06:11,680
is ozone at the surface and we call that

173
00:06:16,710 --> 00:06:13,280
smog

174
00:06:19,830 --> 00:06:16,720
now the ozone layer in the stratosphere

175
00:06:21,430 --> 00:06:19,840
forms naturally from the interaction of

176
00:06:24,870 --> 00:06:21,440
ultraviolet light

177
00:06:28,070 --> 00:06:24,880
and oxygen so if a planet's

178
00:06:30,070 --> 00:06:28,080
atmosphere has oxygen it's

179
00:06:31,749 --> 00:06:30,080
very likely that it's going to develop

180
00:06:33,670 --> 00:06:31,759
an ozone layer

181
00:06:35,430 --> 00:06:33,680
so if we're looking for earth-like

182
00:06:37,749 --> 00:06:35,440
planets out there

183
00:06:40,309 --> 00:06:37,759
then we'd love to be able to tell do

184
00:06:41,909 --> 00:06:40,319
they have an ozone layer

185
00:06:44,070 --> 00:06:41,919
how are we going to find it because we

186
00:06:45,350 --> 00:06:44,080
haven't found any extrasolar planets

187
00:06:47,110 --> 00:06:45,360
that have an ozone layer

188
00:06:48,950 --> 00:06:47,120

and actually we're not really sure even

189
00:06:51,670 --> 00:06:48,960
if it's detectable

190
00:06:53,589 --> 00:06:51,680
so this is where the moon comes in

191
00:06:54,870 --> 00:06:53,599
because there is one planet we know that

192
00:06:57,589 --> 00:06:54,880
has an ozone layer

193
00:06:58,550 --> 00:06:57,599
and that's the earth and we can see if

194
00:07:02,950 --> 00:06:58,560
we can see

195
00:07:06,230 --> 00:07:02,960
ozone from the earth using the moon

196
00:07:08,870 --> 00:07:06,240
during a lunar eclipse so this

197
00:07:09,909 --> 00:07:08,880
is the geometry of a lunar eclipse and

198
00:07:11,990 --> 00:07:09,919
the light is

199
00:07:13,589 --> 00:07:12,000
blocked by the sun and the moon is in a

200
00:07:15,830 --> 00:07:13,599
total lunar eclipse

201
00:07:17,350 --> 00:07:15,840
and some of the light passes through

202
00:07:20,790 --> 00:07:17,360
earth's atmosphere

203
00:07:22,390 --> 00:07:20,800
and is refracted onto the moon so

204
00:07:24,390 --> 00:07:22,400
like the light going through an extra

205
00:07:26,629 --> 00:07:24,400
solar planet that we observe

206
00:07:28,390 --> 00:07:26,639
here the light is coming from the sun

207
00:07:31,110 --> 00:07:28,400
through earth's atmosphere

208
00:07:31,749 --> 00:07:31,120
going to the moon reflected off the moon

209
00:07:35,670 --> 00:07:31,759
and we

210
00:07:38,870 --> 00:07:35,680
study the moon to see earth's atmosphere

211
00:07:39,510 --> 00:07:38,880
that is exactly what hubble did hubble

212
00:07:42,230 --> 00:07:39,520
studied

213
00:07:44,390 --> 00:07:42,240

approximately this portion of the moon

214
00:07:47,589 --> 00:07:44,400
during a total solar eclipse

215
00:07:48,710 --> 00:07:47,599
in order to get the reflected light due

216
00:07:50,309 --> 00:07:48,720
to earth get rid of the

217
00:07:51,749 --> 00:07:50,319
light you know take the light out that

218
00:07:53,830 --> 00:07:51,759
would normally come from the moon

219
00:07:55,909 --> 00:07:53,840
subtract that off and leave the

220
00:07:59,110 --> 00:07:55,919
reflected light of earth's atmosphere

221
00:08:02,150 --> 00:07:59,120
and the cool thing was that yes we were

222
00:08:03,510 --> 00:08:02,160
able to study the ozone in uh earth's

223
00:08:05,670 --> 00:08:03,520
atmosphere we're able to detect the

224
00:08:07,830 --> 00:08:05,680
ozone and earth's atmosphere

225
00:08:08,710 --> 00:08:07,840
and that's a really cool thing so that

226
00:08:11,430 --> 00:08:08,720
if there is an

227
00:08:11,990 --> 00:08:11,440
ozone layer in an extrasolar planet

228
00:08:14,390 --> 00:08:12,000
we've now

229
00:08:16,070 --> 00:08:14,400
with hubble confirmed that we should be

230
00:08:18,950 --> 00:08:16,080
able to see it

231
00:08:20,710 --> 00:08:18,960
and these ozone layers as i said

232
00:08:23,990 --> 00:08:20,720
probably indicative that there is

233
00:08:24,629 --> 00:08:24,000
oxygen and provide more evidence that

234
00:08:27,029 --> 00:08:24,639
the planet

235
00:08:29,430 --> 00:08:27,039
extrasolar planet that we're looking at

236
00:08:33,029 --> 00:08:29,440
might be an earth-like planet

237
00:08:34,070 --> 00:08:33,039
that's kind of cool our second story for

238
00:08:37,430 --> 00:08:34,080

you tonight

239
00:08:39,909 --> 00:08:37,440
is hubble's view of comet neowise

240
00:08:41,750 --> 00:08:39,919
now you may remember back in july we

241
00:08:44,470 --> 00:08:41,760
talked about comet neo eyes

242
00:08:46,630 --> 00:08:44,480
and i showed lots of pictures like this

243
00:08:47,269 --> 00:08:46,640
you know comet neowise sitting in in the

244
00:08:49,190 --> 00:08:47,279
sky

245
00:08:51,430 --> 00:08:49,200
i hope some of you were able to go out

246
00:08:51,910 --> 00:08:51,440
there and look at it with binoculars and

247
00:08:54,150 --> 00:08:51,920
see it

248
00:08:56,070 --> 00:08:54,160
because it's very few rare that you get

249
00:08:57,990 --> 00:08:56,080
a good naked eye comment

250
00:08:59,269 --> 00:08:58,000
and of course hubble is going to take a

251
00:09:01,509 --> 00:08:59,279
look at it but

252
00:09:02,550 --> 00:09:01,519
this is a wide field dude this is tens

253
00:09:05,750 --> 00:09:02,560
you know

254
00:09:06,150 --> 00:09:05,760
50 degrees wide uh hubble doesn't have

255
00:09:08,710 --> 00:09:06,160
quite

256
00:09:10,949 --> 00:09:08,720
that field of view a matter of fact

257
00:09:11,430 --> 00:09:10,959
hubble's field of view is really small

258
00:09:15,110 --> 00:09:11,440
so

259
00:09:18,150 --> 00:09:15,120
if we zoom in to that wide heel picture

260
00:09:21,030 --> 00:09:18,160
and then we zoom in again to that uh

261
00:09:22,470 --> 00:09:21,040
that that picture that that pull out

262
00:09:25,829 --> 00:09:22,480
take a couple levels of zoom

263
00:09:28,790 --> 00:09:25,839

you can see the tiny tiny field of view

264
00:09:30,389 --> 00:09:28,800
that hubble has so hubble isn't seeing

265
00:09:33,350 --> 00:09:30,399
the big long tail that's not what

266
00:09:35,110 --> 00:09:33,360
hubble does hubble looks right in at the

267
00:09:38,070 --> 00:09:35,120
nucleus of a comet

268
00:09:38,949 --> 00:09:38,080
and it's looking at the details right in

269
00:09:41,750 --> 00:09:38,959
the very center

270
00:09:42,630 --> 00:09:41,760
that that the the giant snowball where

271
00:09:44,949 --> 00:09:42,640
the ices

272
00:09:46,230 --> 00:09:44,959
are evaporating away and then being

273
00:09:49,509 --> 00:09:46,240
blown back into

274
00:09:50,150 --> 00:09:49,519
the tail and so this is hubble's view of

275
00:09:52,949 --> 00:09:50,160
the

276
00:09:54,230 --> 00:09:52,959
nucleus and even hubble doesn't resolve

277
00:09:56,310 --> 00:09:54,240
the nucleus okay it's

278
00:09:57,990 --> 00:09:56,320
still unresolved in that white dot there

279
00:09:58,470 --> 00:09:58,000
in the center but you can see that

280
00:10:01,350 --> 00:09:58,480
there's an

281
00:10:02,069 --> 00:10:01,360
asymmetric spray of stuff coming out of

282
00:10:04,870 --> 00:10:02,079
it

283
00:10:06,150 --> 00:10:04,880
matter of fact hubble actually saw a jet

284
00:10:08,389 --> 00:10:06,160
of material

285
00:10:09,190 --> 00:10:08,399
and the comet rotating it took a couple

286
00:10:11,030 --> 00:10:09,200
pictures

287
00:10:12,949 --> 00:10:11,040
um and here are two of them in an

288
00:10:15,590 --> 00:10:12,959

animated gif

289
00:10:16,870 --> 00:10:15,600
where you can see that the jet that's

290
00:10:19,910 --> 00:10:16,880
spewing this material

291
00:10:22,310 --> 00:10:19,920
is rotating between the images

292
00:10:23,670 --> 00:10:22,320
so the comet nucleus is rotating and

293
00:10:24,870 --> 00:10:23,680
there's a jet that's spewing out

294
00:10:28,069 --> 00:10:24,880
material

295
00:10:28,949 --> 00:10:28,079
and hubble can actually see the rotation

296
00:10:32,230 --> 00:10:28,959
of that

297
00:10:33,430 --> 00:10:32,240
jet so while hubble isn't going to give

298
00:10:35,910 --> 00:10:33,440
you these

299
00:10:37,990 --> 00:10:35,920
gorgeous pictures in a wide field with a

300
00:10:39,509 --> 00:10:38,000
big long comet tail

301
00:10:41,590 --> 00:10:39,519
hubble will be able to get to the

302
00:10:44,069 --> 00:10:41,600
details and

303
00:10:45,670 --> 00:10:44,079
for the scientists all the really cool

304
00:10:46,310 --> 00:10:45,680
stuff that we want to understand about

305
00:10:48,310 --> 00:10:46,320
it

306
00:10:49,430 --> 00:10:48,320
really does happen right down in that

307
00:10:52,550 --> 00:10:49,440
nucleus

308
00:10:54,790 --> 00:10:52,560
so hubble will get can give us that and

309
00:10:57,269 --> 00:10:54,800
complement these gorgeous images that i

310
00:10:58,630 --> 00:10:57,279
showed you back in july

311
00:11:01,030 --> 00:10:58,640
all right that's it for our news from

312
00:11:04,150 --> 00:11:01,040
the universe we're now going to go

313
00:11:05,910 --> 00:11:04,160

to our featured speaker and i will

314
00:11:09,110 --> 00:11:05,920
switch over to him

315
00:11:10,790 --> 00:11:09,120
our featured speaker is will fisher uh

316
00:11:13,750 --> 00:11:10,800
from the space telescope science

317
00:11:14,630 --> 00:11:13,760
institute uh he has been at space

318
00:11:18,389 --> 00:11:14,640
telescope for

319
00:11:21,430 --> 00:11:18,399
four years he's uh and it's uh stsci

320
00:11:22,069 --> 00:11:21,440
scientist uh on the cost team where he

321
00:11:24,630 --> 00:11:22,079
provides

322
00:11:25,110 --> 00:11:24,640
user support so all the astronomers who

323
00:11:28,310 --> 00:11:25,120
want to

324
00:11:29,030 --> 00:11:28,320
use the uh uh the cosmic origin

325
00:11:30,630 --> 00:11:29,040
spectrograph

326
00:11:32,150 --> 00:11:30,640
he's the kind of guy who goes in and

327
00:11:32,710 --> 00:11:32,160
helps them get the best out of their

328
00:11:34,389 --> 00:11:32,720
data

329
00:11:36,150 --> 00:11:34,399
that's one of the reasons hubble is so

330
00:11:36,870 --> 00:11:36,160
productive is that we got this great

331
00:11:39,509 --> 00:11:36,880
team

332
00:11:42,150 --> 00:11:39,519
that helps users of the telescope get

333
00:11:44,389 --> 00:11:42,160
the most out of their data

334
00:11:46,069 --> 00:11:44,399
before he's been here for about four

335
00:11:47,110 --> 00:11:46,079
years and before that he did some

336
00:11:49,509 --> 00:11:47,120
post-docs

337
00:11:50,470 --> 00:11:49,519
at the goddard space flight center and

338
00:11:53,750 --> 00:11:50,480

at the

339
00:11:57,829 --> 00:11:53,760
university of toledo he got his phd

340
00:12:00,629 --> 00:11:57,839
at the university of massachusetts and

341
00:12:02,150 --> 00:12:00,639
i asked him you know what's one of those

342
00:12:03,990 --> 00:12:02,160
interesting things that happened to you

343
00:12:06,389 --> 00:12:04,000
during your astronomy career

344
00:12:08,949 --> 00:12:06,399
and he told me about this time when he

345
00:12:13,030 --> 00:12:08,959
was going up to do observing on

346
00:12:16,150 --> 00:12:13,040
at the telescope and it was thanksgiving

347
00:12:18,389 --> 00:12:16,160
but they had to get up to the telescope

348
00:12:19,990 --> 00:12:18,399
so they couldn't go out for for a normal

349
00:12:22,629 --> 00:12:20,000
thanksgiving dinner

350
00:12:25,829 --> 00:12:22,639
and he and his advisor ended up having

351
00:12:27,590 --> 00:12:25,839
thanksgiving dinner at a gas station

352
00:12:29,990 --> 00:12:27,600
all right so this is what you do you

353
00:12:32,710 --> 00:12:30,000
sacrifice for your

354
00:12:33,110 --> 00:12:32,720
your science ladies and gentlemen dr

355
00:12:37,350 --> 00:12:33,120
will

356
00:12:39,509 --> 00:12:37,360
fisher well thanks for coming everyone

357
00:12:41,910 --> 00:12:39,519
and for for bearing with us in this

358
00:12:43,430 --> 00:12:41,920
online kind of unusual format

359
00:12:44,949 --> 00:12:43,440
so today i'm going to be telling you

360
00:12:46,870 --> 00:12:44,959
about our a program

361
00:12:49,430 --> 00:12:46,880
called ulysses that we're doing with

362
00:12:52,790 --> 00:12:49,440
hubble and it's a program to observe

363
00:12:54,710 --> 00:12:52,800

ultraviolet light from young stars so

364
00:12:57,670 --> 00:12:54,720
i'm going to start off by telling you

365
00:12:59,990 --> 00:12:57,680
about what all that means exactly

366
00:13:01,350 --> 00:13:00,000
ulysses is an acronym you notice it's

367
00:13:01,910 --> 00:13:01,360
maybe spelled a little bit different

368
00:13:05,430 --> 00:13:01,920
from

369
00:13:06,949 --> 00:13:05,440
the hero ulysses of mythology it stands

370
00:13:10,069 --> 00:13:06,959
for the ultraviolet

371
00:13:12,310 --> 00:13:10,079
legacy library of young stars as

372
00:13:14,310 --> 00:13:12,320
essential standards

373
00:13:15,670 --> 00:13:14,320
and what this is is a hubble program to

374
00:13:19,110 --> 00:13:15,680
observe young stars

375
00:13:20,949 --> 00:13:19,120
in the milky way and nearby galaxies as

376
00:13:23,030 --> 00:13:20,959
well

377
00:13:24,069 --> 00:13:23,040
now your average hubble observing

378
00:13:26,870 --> 00:13:24,079
program

379
00:13:28,629 --> 00:13:26,880
works in the following way it's led by

380
00:13:30,949 --> 00:13:28,639
one or more astronomers who

381
00:13:32,790 --> 00:13:30,959
put in a proposal and the proposal was

382
00:13:34,550 --> 00:13:32,800
compared to proposals from astronomers

383
00:13:37,750 --> 00:13:34,560
all over the world and

384
00:13:40,069 --> 00:13:37,760
you know the the best ones get time

385
00:13:42,069 --> 00:13:40,079
we at space telescope help these

386
00:13:44,230 --> 00:13:42,079
astronomers use their telescope time

387
00:13:45,829 --> 00:13:44,240
efficiently and help them make the most

388
00:13:48,550 --> 00:13:45,839

of their data

389
00:13:50,389 --> 00:13:48,560
and when the data come in only the

390
00:13:53,829 --> 00:13:50,399
primary investigator and their team

391
00:13:54,870 --> 00:13:53,839
can access the data at first ulysses is

392
00:13:56,629 --> 00:13:54,880
different

393
00:13:58,230 --> 00:13:56,639
the staff at the institute plan and

394
00:14:00,069 --> 00:13:58,240
implement it not just on our own but

395
00:14:01,590 --> 00:14:00,079
with input from the worldwide scientific

396
00:14:04,629 --> 00:14:01,600
community

397
00:14:05,110 --> 00:14:04,639
all the data go public immediately so

398
00:14:10,230 --> 00:14:05,120
there's

399
00:14:12,470 --> 00:14:10,240
other programs you might have heard of

400
00:14:15,509 --> 00:14:12,480
before like the hubble deep field

401
00:14:15,990 --> 00:14:15,519
that that was observed you know closer

402
00:14:17,509 --> 00:14:16,000
to the

403
00:14:19,269 --> 00:14:17,519
beginning of hubble's mission or the

404
00:14:20,710 --> 00:14:19,279
frontier fields

405
00:14:22,790 --> 00:14:20,720
and this is an approach that we use

406
00:14:23,990 --> 00:14:22,800
sometime for major investments of

407
00:14:26,310 --> 00:14:24,000
observing time

408
00:14:27,670 --> 00:14:26,320
that appeal to broad segments of the

409
00:14:30,310 --> 00:14:27,680
community but maybe

410
00:14:32,310 --> 00:14:30,320
are just larger chunks of time than any

411
00:14:34,230 --> 00:14:32,320
one investigator is likely to get on

412
00:14:36,790 --> 00:14:34,240
their own

413
00:14:38,629 --> 00:14:36,800

so those are just the basics of ulysses

414
00:14:39,590 --> 00:14:38,639
but to give you the context for all this

415
00:14:43,110 --> 00:14:39,600
we're going to

416
00:14:44,550 --> 00:14:43,120
kind of go back a few hundred years when

417
00:14:46,790 --> 00:14:44,560
astronomy was a very different

418
00:14:47,590 --> 00:14:46,800
discipline and give you a little bit of

419
00:14:53,189 --> 00:14:47,600
history to

420
00:14:58,069 --> 00:14:56,470
so in

421
00:14:59,590 --> 00:14:58,079
the early days of astronomy before the

422
00:15:01,990 --> 00:14:59,600
19th century

423
00:15:03,189 --> 00:15:02,000
astronomers focused mainly on mapping

424
00:15:04,470 --> 00:15:03,199
stars

425
00:15:06,949 --> 00:15:04,480
looking at their brightnesses and

426
00:15:08,629 --> 00:15:06,959
positions and then figuring out the

427
00:15:10,790 --> 00:15:08,639
nature of the solar system

428
00:15:12,150 --> 00:15:10,800
and how the solar system has arranged

429
00:15:14,790 --> 00:15:12,160
but nobody had any idea

430
00:15:16,870 --> 00:15:14,800
what celestial objects were made of here

431
00:15:18,870 --> 00:15:16,880
i'm showing you an image of

432
00:15:19,990 --> 00:15:18,880
orion and taurus and some of the winter

433
00:15:22,870 --> 00:15:20,000
constellations

434
00:15:24,150 --> 00:15:22,880
a map drawn by hand by flamsteed in his

435
00:15:25,509 --> 00:15:24,160
celestial atlas

436
00:15:27,189 --> 00:15:25,519
and you can see a lot of the figures

437
00:15:27,750 --> 00:15:27,199
that were drawn to accompany the stars

438
00:15:30,230 --> 00:15:27,760

and

439
00:15:31,030 --> 00:15:30,240
give you a sense for the mythology that

440
00:15:34,870 --> 00:15:31,040
was going on

441
00:15:37,189 --> 00:15:34,880
in the sky at about the same or

442
00:15:38,069 --> 00:15:37,199
you know similar times in history

443
00:15:39,749 --> 00:15:38,079
copernicus

444
00:15:41,829 --> 00:15:39,759
made careful you know worked with

445
00:15:44,069 --> 00:15:41,839
careful observations of the solar system

446
00:15:44,949 --> 00:15:44,079
to figure out how the planets were

447
00:15:46,550 --> 00:15:44,959
arranged

448
00:15:48,470 --> 00:15:46,560
for millennia people had thought earth

449
00:15:48,949 --> 00:15:48,480
was at the center of the solar system

450
00:15:51,590 --> 00:15:48,959
but

451
00:15:53,749 --> 00:15:51,600
copernicus put forward his heliocentric

452
00:15:56,069 --> 00:15:53,759
model of the sun being at the center

453
00:15:57,030 --> 00:15:56,079
and the planets in the order that we're

454
00:15:59,110 --> 00:15:57,040
aware of today

455
00:16:00,389 --> 00:15:59,120
with the moon orbiting earth you'll

456
00:16:01,990 --> 00:16:00,399
notice in this diagram

457
00:16:03,910 --> 00:16:02,000
saturn is the last planet and then

458
00:16:07,189 --> 00:16:03,920
beyond that there's kind of a

459
00:16:09,189 --> 00:16:07,199
fixed sphere of stars so

460
00:16:10,870 --> 00:16:09,199
you know the solar system was figured

461
00:16:13,030 --> 00:16:10,880
out in a lot of detail but people didn't

462
00:16:14,470 --> 00:16:13,040
really understand what the stars were

463
00:16:17,670 --> 00:16:14,480

there's another image here showing

464
00:16:20,310 --> 00:16:17,680
galileo's sketches of jupiter's moons

465
00:16:21,990 --> 00:16:20,320
galileo was the first astronomer to use

466
00:16:23,829 --> 00:16:22,000
a telescope to study the sky

467
00:16:25,509 --> 00:16:23,839
and he discovered that jupiter had moons

468
00:16:27,189 --> 00:16:25,519
and their positions changed with respect

469
00:16:27,670 --> 00:16:27,199
to jupiter and with respect to each

470
00:16:30,230 --> 00:16:27,680
other

471
00:16:31,749 --> 00:16:30,240
from night to night so lots of important

472
00:16:33,829 --> 00:16:31,759
work was being done but there was still

473
00:16:34,470 --> 00:16:33,839
no understanding of the stars and

474
00:16:37,269 --> 00:16:34,480
planets

475
00:16:38,629 --> 00:16:37,279
as real objects that one could

476
00:16:40,949 --> 00:16:38,639
conceivably go to

477
00:16:43,990 --> 00:16:40,959
and study in detail given the right

478
00:16:47,990 --> 00:16:47,030
at the same time physicists were making

479
00:16:51,030 --> 00:16:48,000
progress

480
00:16:52,470 --> 00:16:51,040
in understanding what light was here's a

481
00:16:54,310 --> 00:16:52,480
little cartoon of

482
00:16:55,990 --> 00:16:54,320
newton passing white light passing

483
00:16:58,069 --> 00:16:56,000
sunlight through a prism

484
00:16:59,350 --> 00:16:58,079
the prism spread that light out into its

485
00:17:02,230 --> 00:16:59,360
colors

486
00:17:02,550 --> 00:17:02,240
so instead of just being one single

487
00:17:04,470 --> 00:17:02,560
thing

488
00:17:06,470 --> 00:17:04,480

light was in some sense made up of

489
00:17:07,909 --> 00:17:06,480
different forms of light

490
00:17:09,909 --> 00:17:07,919
different you know light with different

491
00:17:12,069 --> 00:17:09,919
colors and different energies

492
00:17:14,390 --> 00:17:12,079
so this was maybe the very beginning of

493
00:17:18,309 --> 00:17:14,400
applying physics to

494
00:17:20,549 --> 00:17:18,319
light that we could receive from the sky

495
00:17:21,590 --> 00:17:20,559
and this spectrum that newton made with

496
00:17:23,669 --> 00:17:21,600
his prism

497
00:17:27,829 --> 00:17:23,679
will be an important feature later on in

498
00:17:33,110 --> 00:17:31,190
in 1835 august compt who for the most

499
00:17:34,710 --> 00:17:33,120
part was a really good philosopher of

500
00:17:35,750 --> 00:17:34,720
science he made a lot of contributions

501
00:17:37,750 --> 00:17:35,760
to understanding

502
00:17:39,430 --> 00:17:37,760
what we do when we do science and the

503
00:17:40,870 --> 00:17:39,440
nature of scientific inquiry

504
00:17:42,710 --> 00:17:40,880
but he said something unfortunate in

505
00:17:44,870 --> 00:17:42,720
1835 he said

506
00:17:46,870 --> 00:17:44,880
i persist in the opinion that every

507
00:17:49,190 --> 00:17:46,880
notion of the true mean temperatures of

508
00:17:51,110 --> 00:17:49,200
stars will necessarily always be

509
00:17:53,029 --> 00:17:51,120
concealed from us

510
00:17:54,549 --> 00:17:53,039
and he had similar things to say about

511
00:17:57,029 --> 00:17:54,559
not just the temperature of the stars

512
00:17:58,710 --> 00:17:57,039
but their their chemical makeup

513
00:18:01,029 --> 00:17:58,720

now this turned out to be a pretty

514
00:18:04,070 --> 00:18:01,039
pretty bad prediction

515
00:18:05,190 --> 00:18:04,080
at just about the same time joseph von

516
00:18:06,950 --> 00:18:05,200
fraunhofer was

517
00:18:09,190 --> 00:18:06,960
studying the spectrum of the sun in in

518
00:18:12,830 --> 00:18:09,200
more detail than newton had

519
00:18:15,430 --> 00:18:12,840
and in this image that we see here

520
00:18:17,029 --> 00:18:15,440
he's you know studying a spectrum and

521
00:18:19,430 --> 00:18:17,039
this is a german postage stamp

522
00:18:21,909 --> 00:18:19,440
commemorating fraunhofer's discovery

523
00:18:24,470 --> 00:18:21,919
he found that in the spectrum of the sun

524
00:18:26,950 --> 00:18:24,480
it wasn't just a continuous spectrum

525
00:18:27,990 --> 00:18:26,960
but it had this array of dark lines in

526
00:18:34,230 --> 00:18:28,000
it

527
00:18:38,710 --> 00:18:37,110
by the 1860s gustav kirkoff had

528
00:18:40,549 --> 00:18:38,720
explained the origin of these spectral

529
00:18:43,350 --> 00:18:40,559
lines

530
00:18:46,870 --> 00:18:43,360
and even today physics students learn

531
00:18:50,150 --> 00:18:49,669
here we have what's labeled a hot black

532
00:18:52,150 --> 00:18:50,160
body

533
00:18:54,390 --> 00:18:52,160
that's kind of a physics name for for a

534
00:18:57,669 --> 00:18:54,400
star just something that's radiating

535
00:18:59,750 --> 00:18:57,679
a lot at all at all wavelengths

536
00:19:01,830 --> 00:18:59,760
if you pass that light through a prism

537
00:19:03,430 --> 00:19:01,840
you might get a continuous spectrum

538
00:19:05,029 --> 00:19:03,440

like you see in the lower left corner of

539
00:19:07,110 --> 00:19:05,039
this image

540
00:19:09,350 --> 00:19:07,120
but if that light passes through a cloud

541
00:19:13,270 --> 00:19:09,360
of cooler gas

542
00:19:16,710 --> 00:19:13,280
then the materials the chemical elements

543
00:19:18,710 --> 00:19:16,720
or or molecules in that gas

544
00:19:20,950 --> 00:19:18,720
will absorb out certain lines in the

545
00:19:21,669 --> 00:19:20,960
spectrum so you get this pattern of dark

546
00:19:23,510 --> 00:19:21,679
lines

547
00:19:25,350 --> 00:19:23,520
that depends on what's actually in that

548
00:19:28,230 --> 00:19:25,360
gas

549
00:19:29,590 --> 00:19:28,240
when we take a spectrum of a star we're

550
00:19:31,029 --> 00:19:29,600
really look you know think of the cloud

551
00:19:32,549 --> 00:19:31,039
of cooler gas in this case as the

552
00:19:33,430 --> 00:19:32,559
outermost layers of the star's

553
00:19:36,070 --> 00:19:33,440
atmosphere

554
00:19:36,549 --> 00:19:36,080
so that so that starlight is passing

555
00:19:38,950 --> 00:19:36,559
through

556
00:19:43,590 --> 00:19:38,960
the outermost parts of the star and that

557
00:19:47,190 --> 00:19:45,270
and it was determined that the lines in

558
00:19:48,789 --> 00:19:47,200
the solar spectrum corresponded to the

559
00:19:51,029 --> 00:19:48,799
patterns of lines

560
00:19:52,950 --> 00:19:51,039
that you could observe on earth if you

561
00:19:55,430 --> 00:19:52,960
passed light through gases in a chemical

562
00:19:58,310 --> 00:19:55,440
laboratory here on earth

563
00:19:59,430 --> 00:19:58,320

if you look at just the gas without the

564
00:20:01,350 --> 00:19:59,440
source behind it

565
00:20:03,029 --> 00:20:01,360
then instead of absorption lines you see

566
00:20:06,310 --> 00:20:03,039
emission lines in exactly the same

567
00:20:09,669 --> 00:20:06,320
pattern as the absorption lines

568
00:20:11,350 --> 00:20:09,679
so this gave scientists the idea that

569
00:20:12,070 --> 00:20:11,360
they could look at the spectra and start

570
00:20:14,789 --> 00:20:12,080
to understand

571
00:20:17,029 --> 00:20:14,799
what the stars were made of and to learn

572
00:20:19,430 --> 00:20:17,039
something about their temperatures

573
00:20:23,270 --> 00:20:19,440
and motions in the stars and near the

574
00:20:27,750 --> 00:20:25,590
this is a modern spectrum of the sun

575
00:20:28,549 --> 00:20:27,760
obtained from the mcmath pierce solar

576
00:20:30,789 --> 00:20:28,559
telescope

577
00:20:32,149 --> 00:20:30,799
upon up at the kit peak observatory in

578
00:20:33,830 --> 00:20:32,159
arizona

579
00:20:36,149 --> 00:20:33,840
and you can see how much detail is

580
00:20:38,630 --> 00:20:36,159
available to modern spectroscopists

581
00:20:39,430 --> 00:20:38,640
you can really spread that starlight out

582
00:20:41,750 --> 00:20:39,440
into

583
00:20:43,350 --> 00:20:41,760
the familiar colors of the spectrum and

584
00:20:45,110 --> 00:20:43,360
you can see just how many absorption

585
00:20:47,029 --> 00:20:45,120
lines there are in this spectrum there's

586
00:20:48,310 --> 00:20:47,039
forests of lines from all sorts of

587
00:20:50,310 --> 00:20:48,320
different

588
00:20:52,549 --> 00:20:50,320

materials that are in this in the solar

589
00:20:54,789 --> 00:20:52,559
atmosphere

590
00:20:57,029 --> 00:20:54,799
so our study of the sun has really been

591
00:20:58,789 --> 00:20:57,039
advanced thanks to spectroscopy

592
00:21:00,310 --> 00:20:58,799
and we can apply these same insights to

593
00:21:05,350 --> 00:21:00,320
other stars as well if we have

594
00:21:08,630 --> 00:21:07,270
so let's talk about some of the things

595
00:21:09,590 --> 00:21:08,640
we can learn from a spectrum in more

596
00:21:11,510 --> 00:21:09,600
detail

597
00:21:13,590 --> 00:21:11,520
if you read the advertisement from this

598
00:21:16,149 --> 00:21:13,600
talk you would have seen words like

599
00:21:17,110 --> 00:21:16,159
a picture is worth a thousand words but

600
00:21:19,669 --> 00:21:17,120
a spectrum

601
00:21:21,590 --> 00:21:19,679
is worth a thousand pictures it can

602
00:21:22,549 --> 00:21:21,600
reveal things about an object's

603
00:21:26,470 --> 00:21:22,559
composition

604
00:21:29,190 --> 00:21:26,480
like we were discussing its temperature

605
00:21:30,070 --> 00:21:29,200
also its density and its velocity how

606
00:21:32,710 --> 00:21:30,080
things are moving

607
00:21:34,149 --> 00:21:32,720
in what direction and how fast this is

608
00:21:35,990 --> 00:21:34,159
just a little schematic showing how

609
00:21:37,830 --> 00:21:36,000
astronomers make a spectrum

610
00:21:39,510 --> 00:21:37,840
we pass light from a star through a

611
00:21:42,789 --> 00:21:39,520
telescope

612
00:21:45,830 --> 00:21:42,799
that starlight is fed maybe through a

613
00:21:48,310 --> 00:21:45,840

fiber optic cable of some kind or maybe

614
00:21:50,390 --> 00:21:48,320
not but it eventually reaches a grating

615
00:21:52,390 --> 00:21:50,400
which is sort of like the prism that

616
00:21:53,750 --> 00:21:52,400
that newton used

617
00:21:55,110 --> 00:21:53,760
the details are a little bit different

618
00:21:57,110 --> 00:21:55,120
but it breaks the light up into its

619
00:21:58,789 --> 00:21:57,120
component colors and we record that

620
00:22:00,310 --> 00:21:58,799
spectrum on a detector

621
00:22:01,909 --> 00:22:00,320
and you can see here the little cartoon

622
00:22:04,390 --> 00:22:01,919
of the rainbow-like spectrum with all

623
00:22:05,909 --> 00:22:04,400
the different absorption lines in it

624
00:22:07,110 --> 00:22:05,919
in practice astronomers look at

625
00:22:08,630 --> 00:22:07,120
something a little bit different when we

626
00:22:12,710 --> 00:22:08,640
actually study a spectrum and we'll get

627
00:22:15,430 --> 00:22:12,720
more into that later

628
00:22:16,789 --> 00:22:15,440
so what about composition can we learn

629
00:22:18,310 --> 00:22:16,799
from a spectrum we've talked about these

630
00:22:19,750 --> 00:22:18,320
different patterns that you get from

631
00:22:22,950 --> 00:22:19,760
different elements

632
00:22:24,310 --> 00:22:22,960
and this is a picture showing many

633
00:22:26,870 --> 00:22:24,320
elements from the periodic

634
00:22:27,750 --> 00:22:26,880
periodic table and all of their

635
00:22:30,230 --> 00:22:27,760
signature

636
00:22:32,070 --> 00:22:30,240
emission lines so you can see like

637
00:22:33,750 --> 00:22:32,080
hydrogen up in the upper left corner has

638
00:22:34,870 --> 00:22:33,760

a pretty simple spectrum with just a few

639
00:22:36,310 --> 00:22:34,880
bright lines

640
00:22:38,070 --> 00:22:36,320
but some of the other elements are much

641
00:22:39,990 --> 00:22:38,080
more complicated

642
00:22:42,070 --> 00:22:40,000
iron for example over here in the upper

643
00:22:43,590 --> 00:22:42,080
right has this wealth of emission lines

644
00:22:46,390 --> 00:22:43,600
all across the spectrum

645
00:22:48,230 --> 00:22:46,400
and it gives astrophysicists a real

646
00:22:50,149 --> 00:22:48,240
challenge in trying to figure out

647
00:22:54,390 --> 00:22:50,159
physical conditions from this whole

648
00:22:56,470 --> 00:22:54,400
forest of iron lines

649
00:22:58,149 --> 00:22:56,480
and you know just as an example of how

650
00:22:59,350 --> 00:22:58,159
we use spectra to study chemical

651
00:23:02,230 --> 00:22:59,360
composition

652
00:23:03,669 --> 00:23:02,240
here i've got an image from hubble of of

653
00:23:05,750 --> 00:23:03,679
a nebula that's

654
00:23:07,190 --> 00:23:05,760
that's pink in color and a lot of the

655
00:23:08,390 --> 00:23:07,200
nebulae that you see in hubble images

656
00:23:10,149 --> 00:23:08,400
have this characteristic

657
00:23:12,390 --> 00:23:10,159
pink color and that's due to that bright

658
00:23:15,669 --> 00:23:12,400
red emission line from hydrogen

659
00:23:16,950 --> 00:23:15,679
that you can see in the diagram here

660
00:23:20,950 --> 00:23:16,960
you've got contributions from other

661
00:23:24,390 --> 00:23:20,960
gases as well but it's mostly hydrogen

662
00:23:25,669 --> 00:23:24,400
this is a little web tool i came across

663
00:23:27,270 --> 00:23:25,679

where you can actually click on

664
00:23:28,549 --> 00:23:27,280
different elements in the periodic table

665
00:23:30,149 --> 00:23:28,559
and look at their spectra

666
00:23:31,830 --> 00:23:30,159
maybe a little in more detail than we

667
00:23:34,230 --> 00:23:31,840
had before

668
00:23:36,630 --> 00:23:34,240
so here's the spectrum of hydrogen with

669
00:23:37,430 --> 00:23:36,640
that bright red line and a few other

670
00:23:41,669 --> 00:23:37,440
lines

671
00:23:44,950 --> 00:23:43,269
oxygen is pretty interesting those

672
00:23:46,870 --> 00:23:44,960
bright green lines that you see there

673
00:23:48,950 --> 00:23:46,880
are what give their color would give

674
00:23:53,430 --> 00:23:48,960
color to the aurora borealis their major

675
00:23:57,190 --> 00:23:55,510
we all know about neon signs if you look

676
00:23:58,870 --> 00:23:57,200
at the spectrum of neon you can see why

677
00:24:02,230 --> 00:23:58,880
they have that characteristic orange

678
00:24:05,590 --> 00:24:04,390
or if you see a blue sign and call it a

679
00:24:07,269 --> 00:24:05,600
neon sign maybe

680
00:24:11,909 --> 00:24:07,279
xenon is actually what's giving it its

681
00:24:16,789 --> 00:24:14,390
and again here's the spectrum of iron

682
00:24:18,390 --> 00:24:16,799
with all those lines

683
00:24:19,830 --> 00:24:18,400
so there's lots of diversity and if you

684
00:24:21,510 --> 00:24:19,840
have multiple different contribute

685
00:24:22,870 --> 00:24:21,520
contributions to a spectrum

686
00:24:24,789 --> 00:24:22,880
it can be a little bit of a puzzle to

687
00:24:32,630 --> 00:24:24,799
figure out what lines go with what

688
00:24:34,870 --> 00:24:32,640

element or what molecule

689
00:24:36,789 --> 00:24:34,880
so what are the stars themselves made of

690
00:24:37,830 --> 00:24:36,799
this is kind of an interesting story in

691
00:24:39,830 --> 00:24:37,840
astronomy we

692
00:24:41,669 --> 00:24:39,840
you know astronomers initially saw lines

693
00:24:44,390 --> 00:24:41,679
in the solar spectrum of carbon

694
00:24:44,870 --> 00:24:44,400
and silicon and other common elements of

695
00:24:49,590 --> 00:24:44,880
earth

696
00:24:51,430 --> 00:24:49,600
assumed that the sun

697
00:24:52,710 --> 00:24:51,440
must have the same composition as earth

698
00:24:54,390 --> 00:24:52,720
only hot enough for everything to be

699
00:24:56,070 --> 00:24:54,400
glowing it's a reasonable assumption to

700
00:24:59,269 --> 00:24:56,080
start with

701
00:25:01,909 --> 00:24:59,279
but in 1925 cecilia payne who was

702
00:25:03,029 --> 00:25:01,919
one of possibly the first american woman

703
00:25:05,750 --> 00:25:03,039
to get a phd

704
00:25:07,750 --> 00:25:05,760
in astronomy concluded from spectral

705
00:25:09,830 --> 00:25:07,760
analysis that the sun was actually made

706
00:25:13,029 --> 00:25:09,840
of hydrogen for the most part

707
00:25:15,110 --> 00:25:13,039
this was very controversial none of the

708
00:25:16,710 --> 00:25:15,120
you know bigwigs in astronomy at the

709
00:25:18,310 --> 00:25:16,720
time believed her but she turned out to

710
00:25:20,630 --> 00:25:18,320
be right

711
00:25:21,669 --> 00:25:20,640
and today we know that stars in our

712
00:25:25,029 --> 00:25:21,679
galaxy

713
00:25:27,909 --> 00:25:25,039

are around 70 hydrogen 25

714
00:25:29,029 --> 00:25:27,919
helium and a few percent everything else

715
00:25:31,430 --> 00:25:29,039
altogether

716
00:25:33,190 --> 00:25:31,440
astronomers have this habit of referring

717
00:25:33,669 --> 00:25:33,200
to the everything else as metals even

718
00:25:35,590 --> 00:25:33,679
things like

719
00:25:36,870 --> 00:25:35,600
oxygen and carbon which are clearly not

720
00:25:38,950 --> 00:25:36,880
metals according to

721
00:25:40,470 --> 00:25:38,960
anybody you know a chemist definition

722
00:25:41,830 --> 00:25:40,480
but we just use that as a shorthand i

723
00:25:43,190 --> 00:25:41,840
mean everything except hydrogen and

724
00:25:45,190 --> 00:25:43,200
helium

725
00:25:46,789 --> 00:25:45,200
and as if you look at stars that are in

726
00:25:48,630 --> 00:25:46,799
other galaxies

727
00:25:50,470 --> 00:25:48,640
further across the universe you find

728
00:25:51,990 --> 00:25:50,480
stars with different metallicities

729
00:25:53,669 --> 00:25:52,000
different fractions of these heavy

730
00:25:54,870 --> 00:25:53,679
elements compared to what we see in the

731
00:25:56,310 --> 00:25:54,880
sun

732
00:26:02,870 --> 00:25:56,320
so that'll become important again when

733
00:26:06,870 --> 00:26:05,029
so temperature is another thing we can

734
00:26:10,149 --> 00:26:06,880
learn from a spectrum

735
00:26:12,390 --> 00:26:10,159
these are stacked spectra from several

736
00:26:16,070 --> 00:26:12,400
different stars

737
00:26:18,230 --> 00:26:16,080
and they've been placed in an order that

738
00:26:20,630 --> 00:26:18,240

that tell that depends on their

739
00:26:23,590 --> 00:26:20,640
temperatures

740
00:26:25,750 --> 00:26:23,600
and you see this column of letters and

741
00:26:27,909 --> 00:26:25,760
numbers over to the right

742
00:26:30,390 --> 00:26:27,919
this is a system we use to classify the

743
00:26:33,430 --> 00:26:30,400
spectra of stars by their temperatures

744
00:26:35,830 --> 00:26:33,440
the o stars are the hottest the

745
00:26:37,750 --> 00:26:35,840
m stars are the coolest and those

746
00:26:37,990 --> 00:26:37,760
numbers that you see next to the letters

747
00:26:39,590 --> 00:26:38,000
are

748
00:26:41,669 --> 00:26:39,600
subclasses they give you a little bit

749
00:26:43,590 --> 00:26:41,679
finer information than just the letters

750
00:26:45,029 --> 00:26:43,600
themselves

751
00:26:46,710 --> 00:26:45,039
the reason the letters come in that

752
00:26:48,470 --> 00:26:46,720
order is that they were actually

753
00:26:51,029 --> 00:26:48,480
first placed in order by the strength of

754
00:26:53,269 --> 00:26:51,039
their hydrogen lines in their spectra

755
00:26:54,230 --> 00:26:53,279
the a stars have the strongest hydrogen

756
00:26:55,430 --> 00:26:54,240
lines

757
00:26:57,830 --> 00:26:55,440
so if you've been looking at this

758
00:26:58,789 --> 00:26:57,840
diagram for the better portion of a

759
00:27:01,669 --> 00:26:58,799
minute now

760
00:27:03,269 --> 00:27:01,679
you might realize that this strong line

761
00:27:05,029 --> 00:27:03,279
about a third of the way from the left

762
00:27:06,950 --> 00:27:05,039
is a hydrogen line and you can see how

763
00:27:08,230 --> 00:27:06,960

it's really strong in the a stars and

764
00:27:11,750 --> 00:27:08,240
there's not much else

765
00:27:13,669 --> 00:27:11,760
in those stars as you go to hotter stars

766
00:27:15,029 --> 00:27:13,679
the b stars have the second strongest

767
00:27:16,630 --> 00:27:15,039
hydrogen lines but then when you go to

768
00:27:17,750 --> 00:27:16,640
the o stars that was you know toward the

769
00:27:19,990 --> 00:27:17,760
end of the alphabet

770
00:27:21,510 --> 00:27:20,000
so when people were first doing this

771
00:27:23,190 --> 00:27:21,520
classification they

772
00:27:25,269 --> 00:27:23,200
placed the o stars toward the end

773
00:27:26,789 --> 00:27:25,279
because the hydrogen lines were so weak

774
00:27:28,870 --> 00:27:26,799
but it's really they're weak because

775
00:27:31,830 --> 00:27:28,880
those stars are so hot

776
00:27:32,389 --> 00:27:31,840
the this the way the the hydrogen atoms

777
00:27:33,830 --> 00:27:32,399
emit

778
00:27:35,909 --> 00:27:33,840
changes as you get to those very high

779
00:27:38,549 --> 00:27:35,919
temperatures

780
00:27:40,149 --> 00:27:38,559
the g k and m stars are much cooler the

781
00:27:40,870 --> 00:27:40,159
hydrogen lines get weak and then you

782
00:27:43,110 --> 00:27:40,880
start to see

783
00:27:44,789 --> 00:27:43,120
many many lines due to what astronomers

784
00:27:47,750 --> 00:27:44,799
call metals

785
00:27:49,909 --> 00:27:47,760
the sun by the way has type g2 so its

786
00:27:53,029 --> 00:27:49,919
spectrum is kind of between the g0 and

787
00:27:56,389 --> 00:27:53,039
the g5 that you see here

788
00:27:58,389 --> 00:27:56,399

so the temperature of the star tells us

789
00:28:01,029 --> 00:27:58,399
what kinds of lines you see

790
00:28:02,389 --> 00:28:01,039
but it also tells us it's also related

791
00:28:05,909 --> 00:28:02,399
to whether the star

792
00:28:08,789 --> 00:28:05,919
is blue or red or somewhere in between

793
00:28:09,190 --> 00:28:08,799
in appearance so we're going to look at

794
00:28:12,549 --> 00:28:09,200
this

795
00:28:14,830 --> 00:28:12,559
stellar temperature simulator

796
00:28:15,990 --> 00:28:14,840
so what we're looking at here is a plot

797
00:28:17,510 --> 00:28:16,000
of

798
00:28:19,430 --> 00:28:17,520
something related to the star's

799
00:28:20,549 --> 00:28:19,440
brightness they call it spectral power

800
00:28:22,149 --> 00:28:20,559
density but that's really just how

801
00:28:25,190 --> 00:28:22,159
bright the star is

802
00:28:26,630 --> 00:28:25,200
as a function of wavelength and the

803
00:28:30,149 --> 00:28:26,640
rainbow shown here

804
00:28:33,590 --> 00:28:30,159
shows you the red orange yellow

805
00:28:36,789 --> 00:28:33,600
green blue and violet that are i see

806
00:28:39,110 --> 00:28:36,799
so what we're looking at here is

807
00:28:41,750 --> 00:28:39,120
roughly the spectrum of the sun although

808
00:28:43,669 --> 00:28:41,760
without any of those absorption lines

809
00:28:45,830 --> 00:28:43,679
and you can see it peaks at visible

810
00:28:48,549 --> 00:28:45,840
wavelengths the reason those wavelengths

811
00:28:51,269 --> 00:28:48,559
of light are visible is because

812
00:28:52,630 --> 00:28:51,279
the eyes of animals and humans evolved

813
00:28:56,070 --> 00:28:52,640

to detect light that was

814
00:28:59,269 --> 00:28:57,830
but if we change our temperature over

815
00:29:02,310 --> 00:28:59,279
here on the slider

816
00:29:05,269 --> 00:29:02,320
if we first go to cooler temperatures

817
00:29:06,470 --> 00:29:05,279
for one thing the star gets fainter and

818
00:29:08,470 --> 00:29:06,480
for another thing that

819
00:29:10,710 --> 00:29:08,480
peak emission starts to go to longer and

820
00:29:12,789 --> 00:29:10,720
longer wavelengths

821
00:29:14,549 --> 00:29:12,799
you'll notice now we're down to about 4

822
00:29:17,029 --> 00:29:14,559
000 kelvin which

823
00:29:19,269 --> 00:29:17,039
is roughly 8 000 degrees fahrenheit you

824
00:29:22,549 --> 00:29:19,279
could work it out exactly but

825
00:29:24,630 --> 00:29:22,559
multiplying by 2 gets you pretty close

826
00:29:26,310 --> 00:29:24,640
and now for these relatively cool stars

827
00:29:28,070 --> 00:29:26,320
the spectrum's peaking at red

828
00:29:30,310 --> 00:29:28,080
wavelengths

829
00:29:32,070 --> 00:29:30,320
and there's a lot of light being emitted

830
00:29:34,470 --> 00:29:32,080
out at longer wavelengths even than we

831
00:29:38,230 --> 00:29:34,480
can see

832
00:29:40,470 --> 00:29:38,240
and we can keep going cooler and cooler

833
00:29:43,750 --> 00:29:40,480
until the star gets quite faint and

834
00:29:48,310 --> 00:29:45,750
now let's start going to large to larger

835
00:29:50,310 --> 00:29:48,320
temperatures we're back to the sun

836
00:29:51,830 --> 00:29:50,320
and now we very quickly start to run off

837
00:29:53,430 --> 00:29:51,840
the top of the plot so let's look at a

838
00:29:54,950 --> 00:29:53,440

little bit more of it let's kind of zoom

839
00:29:56,149 --> 00:29:54,960
out

840
00:29:57,990 --> 00:29:56,159
and now as we're getting hotter and

841
00:30:00,149 --> 00:29:58,000
hotter look at how that peak goes

842
00:30:02,389 --> 00:30:00,159
even past the violet into the

843
00:30:04,070 --> 00:30:02,399
ultraviolet

844
00:30:06,310 --> 00:30:04,080
and you can see how hot stars are

845
00:30:08,549 --> 00:30:06,320
emitting most of their energy there

846
00:30:10,310 --> 00:30:08,559
and to our eyes they start to appear

847
00:30:11,750 --> 00:30:10,320
blue because most of the visible light

848
00:30:15,110 --> 00:30:11,760
is coming out

849
00:30:19,029 --> 00:30:16,630
so this discovery the of the

850
00:30:20,950 --> 00:30:19,039
relationship between the temperature

851
00:30:22,470 --> 00:30:20,960
of a star and its color was very

852
00:30:24,230 --> 00:30:22,480
important in helping

853
00:30:26,789 --> 00:30:24,240
astronomers to start making headway on

854
00:30:30,070 --> 00:30:26,799
understanding stellar evolution

855
00:30:37,110 --> 00:30:30,080
how stars change as they go through

856
00:30:39,669 --> 00:30:37,120
what we think of as a life life cycle

857
00:30:41,830 --> 00:30:39,679
what about density here are some spectra

858
00:30:44,710 --> 00:30:41,840
obtained long ago of different stars

859
00:30:46,870 --> 00:30:44,720
and they've got they've all got strong

860
00:30:47,990 --> 00:30:46,880
hydrogen lines but the hydrogen lines

861
00:30:49,669 --> 00:30:48,000
look a little bit different from one

862
00:30:52,950 --> 00:30:49,679
star to the next

863
00:30:53,669 --> 00:30:52,960

the one labeled hr 1040 that's a very

864
00:30:56,870 --> 00:30:53,679
luminous

865
00:30:57,190 --> 00:30:56,880
large giant star and these giant stars

866
00:30:59,909 --> 00:30:57,200
have

867
00:31:00,789 --> 00:30:59,919
low density what this means is that the

868
00:31:04,070 --> 00:31:00,799
atoms

869
00:31:08,789 --> 00:31:04,080
and ions in the star itself

870
00:31:10,789 --> 00:31:08,799
are moving around relative to each other

871
00:31:11,909 --> 00:31:10,799
not not that not not so fast because the

872
00:31:14,950 --> 00:31:11,919
density is

873
00:31:17,029 --> 00:31:14,960
low so you get these these narrow lines

874
00:31:19,269 --> 00:31:17,039
but in the higher density

875
00:31:21,430 --> 00:31:19,279
we call them dwarf stars they're not

876
00:31:23,350 --> 00:31:21,440
really like tiny stars but they're much

877
00:31:25,590 --> 00:31:23,360
smaller than the giants

878
00:31:26,950 --> 00:31:25,600
there the pressure in the layer outer

879
00:31:28,630 --> 00:31:26,960
layers of the star's atmosphere is quite

880
00:31:31,669 --> 00:31:28,640
a bit larger and that causes the lines

881
00:31:33,830 --> 00:31:31,679
to broaden so you can look at the width

882
00:31:34,950 --> 00:31:33,840
of a spectral line and learn something

883
00:31:37,269 --> 00:31:34,960
about the density

884
00:31:40,710 --> 00:31:37,279
of the material that's responsible for

885
00:31:46,870 --> 00:31:43,750
we can also learn about velocity

886
00:31:48,630 --> 00:31:46,880
i'm showing a thumb a stock image of a

887
00:31:50,230 --> 00:31:48,640
mark train here because it's relevant

888
00:31:51,750 --> 00:31:50,240

but also because in this work from home

889
00:31:53,509 --> 00:31:51,760
environment i kind of miss taking the

890
00:31:54,789 --> 00:31:53,519
mark train back and forth to baltimore

891
00:31:58,710 --> 00:31:54,799
every day but

892
00:32:01,430 --> 00:31:58,720
the reason it's it's relevant for this

893
00:32:02,549 --> 00:32:01,440
is if you just think about the whistles

894
00:32:04,310 --> 00:32:02,559
the trains

895
00:32:05,990 --> 00:32:04,320
make you can hear from miles away

896
00:32:09,029 --> 00:32:06,000
sometimes

897
00:32:09,990 --> 00:32:09,039
if a train is moving toward you the

898
00:32:12,070 --> 00:32:10,000
pitch

899
00:32:13,830 --> 00:32:12,080
of the train whistle increases it's

900
00:32:14,950 --> 00:32:13,840
almost like the sound waves are getting

901
00:32:18,149 --> 00:32:14,960
smushed together

902
00:32:19,430 --> 00:32:18,159
and start to take on a higher pitch as

903
00:32:21,909 --> 00:32:19,440
that train

904
00:32:23,269 --> 00:32:21,919
passes and then moves away from you the

905
00:32:27,350 --> 00:32:23,279
pitch of the sound

906
00:32:30,549 --> 00:32:27,360
gets lower and lower light does that too

907
00:32:33,590 --> 00:32:30,559
we call it the doppler shift and when

908
00:32:36,389 --> 00:32:33,600
a star is moving away from us

909
00:32:38,870 --> 00:32:36,399
its lines can be redshifted they shift

910
00:32:41,269 --> 00:32:38,880
to longer redder wavelengths

911
00:32:41,990 --> 00:32:41,279
if a star or something near the star is

912
00:32:44,070 --> 00:32:42,000
moving toward

913
00:32:46,070 --> 00:32:44,080

us then you see a blue shift and the

914
00:32:48,149 --> 00:32:46,080
lines go to shorter wavelengths

915
00:32:49,509 --> 00:32:48,159
so velocity is an important thing that

916
00:32:54,470 --> 00:32:49,519
we learned from spectra

917
00:32:58,630 --> 00:32:56,070
so putting together some of the things

918
00:33:00,389 --> 00:32:58,640
we can learn from stellar spectra

919
00:33:03,430 --> 00:33:00,399
one thing we've come to know is that

920
00:33:04,870 --> 00:33:03,440
stars differ greatly from one another

921
00:33:07,909 --> 00:33:04,880
they have an enormous range of

922
00:33:10,230 --> 00:33:07,919
luminosities and surface temperatures

923
00:33:11,350 --> 00:33:10,240
now luminosity probably realize that

924
00:33:11,830 --> 00:33:11,360
that word has something to do with the

925
00:33:13,909 --> 00:33:11,840
total

926
00:33:16,310 --> 00:33:13,919
energy output from the star how bright

927
00:33:19,190 --> 00:33:16,320
it is it's related to its size

928
00:33:20,789 --> 00:33:19,200
its temperature and it varies incredibly

929
00:33:23,029 --> 00:33:20,799
from start to start in this

930
00:33:24,549 --> 00:33:23,039
schematic diagram here you can see a red

931
00:33:26,549 --> 00:33:24,559
dwarf star

932
00:33:28,310 --> 00:33:26,559
its luminosity is less than one percent

933
00:33:30,630 --> 00:33:28,320
of the sun's

934
00:33:33,430 --> 00:33:30,640
these are very small stars that burn

935
00:33:36,870 --> 00:33:33,440
their nuclear fuel very efficiently

936
00:33:38,070 --> 00:33:36,880
and they exist they'll exist for much

937
00:33:40,389 --> 00:33:38,080
longer than the current age of the

938
00:33:42,070 --> 00:33:40,399

universe

939
00:33:43,750 --> 00:33:42,080
then you have the sun which is kind of a

940
00:33:45,350 --> 00:33:43,760
typical

941
00:33:47,350 --> 00:33:45,360
middle sized maybe a little bit above

942
00:33:49,190 --> 00:33:47,360
average size star

943
00:33:50,950 --> 00:33:49,200
but the giants and supergiants are the

944
00:33:53,110 --> 00:33:50,960
most luminous stars

945
00:33:55,110 --> 00:33:53,120
a blue white supergiant star can have a

946
00:33:55,830 --> 00:33:55,120
luminosity up to a million times that of

947
00:33:58,070 --> 00:33:55,840
the sun

948
00:33:59,990 --> 00:33:58,080
and these stars burn through their fuel

949
00:34:01,669 --> 00:34:00,000
really quickly as far as stars go and

950
00:34:04,870 --> 00:34:01,679
may only exist for 10 million years

951
00:34:09,430 --> 00:34:07,590
surface temperatures also vary a lot for

952
00:34:11,589 --> 00:34:09,440
the red stars the surface temperature is

953
00:34:13,430 --> 00:34:11,599
maybe 5 000 degrees fahrenheit

954
00:34:15,030 --> 00:34:13,440
the sun's about 10 000 degrees at its

955
00:34:18,470 --> 00:34:15,040
surface and these hot blue stars can be

956
00:34:21,030 --> 00:34:18,480
70 000 degrees or more at their surfaces

957
00:34:23,669 --> 00:34:21,040
so there's this whole whole zoo of

958
00:34:25,990 --> 00:34:23,679
different stellar types

959
00:34:27,510 --> 00:34:26,000
and you know astronomers and

960
00:34:28,710 --> 00:34:27,520
spectroscopists want to study all of

961
00:34:30,470 --> 00:34:28,720
them to understand how

962
00:34:32,829 --> 00:34:30,480
how what else changes about the stars

963
00:34:35,109 --> 00:34:32,839

besides their luminosities and

964
00:34:38,869 --> 00:34:35,119
temperatures

965
00:34:41,430 --> 00:34:38,879
so to make sense of all this around 1910

966
00:34:42,950 --> 00:34:41,440
the astronomers heard sprung and russell

967
00:34:44,790 --> 00:34:42,960
plotted the luminosities and

968
00:34:46,310 --> 00:34:44,800
temperatures of stars on the same

969
00:34:47,990 --> 00:34:46,320
diagram

970
00:34:49,669 --> 00:34:48,000
they put temperature in reverse and

971
00:34:49,990 --> 00:34:49,679
astronomers continue to do that today

972
00:34:52,069 --> 00:34:50,000
with

973
00:34:53,909 --> 00:34:52,079
hot blue stars at the left and cool red

974
00:34:55,909 --> 00:34:53,919
stars at the right

975
00:34:57,510 --> 00:34:55,919
and what they notice is that most of the

976
00:34:59,430 --> 00:34:57,520
stars that they observed

977
00:35:01,109 --> 00:34:59,440
appeared on this diagonal line that goes

978
00:35:02,230 --> 00:35:01,119
from upper left to lower right more or

979
00:35:05,589 --> 00:35:02,240
less

980
00:35:07,589 --> 00:35:05,599
this was named the main sequence and as

981
00:35:09,829 --> 00:35:07,599
the theoretical understanding of stellar

982
00:35:12,470 --> 00:35:09,839
evolution came along

983
00:35:14,790 --> 00:35:12,480
people realized that stars move through

984
00:35:17,349 --> 00:35:14,800
what we call the hr diagram

985
00:35:18,950 --> 00:35:17,359
over their life cycles the reason so

986
00:35:20,390 --> 00:35:18,960
many stars are on the main sequence is

987
00:35:23,670 --> 00:35:20,400
because that's where stars spend

988
00:35:25,190 --> 00:35:23,680

most of their time and

989
00:35:27,349 --> 00:35:25,200
the path of a star through the main

990
00:35:33,990 --> 00:35:27,359
sequence it varies from star to star and

991
00:35:38,150 --> 00:35:35,829
this is a different hr diagram it

992
00:35:38,870 --> 00:35:38,160
doesn't show any actual stars except the

993
00:35:40,870 --> 00:35:38,880
sun

994
00:35:42,230 --> 00:35:40,880
that it shows the paths that stars of

995
00:35:45,430 --> 00:35:42,240
different masses

996
00:35:47,270 --> 00:35:45,440
take through the hr diagram

997
00:35:48,870 --> 00:35:47,280
all of these paths here show how these

998
00:35:50,550 --> 00:35:48,880
start what these stars do

999
00:35:53,349 --> 00:35:50,560
early in their life cycles before they

1000
00:35:55,670 --> 00:35:53,359
reach the main sequence

1001
00:35:57,430 --> 00:35:55,680
ulysses is studying both kinds of stars

1002
00:36:00,550 --> 00:35:57,440
massive and low-mass stars

1003
00:36:03,109 --> 00:36:00,560
about 50 50 between the two

1004
00:36:04,950 --> 00:36:03,119
low mass young stars like you can see

1005
00:36:06,470 --> 00:36:04,960
here for the one solar mass and half

1006
00:36:08,150 --> 00:36:06,480
solar mass star

1007
00:36:10,550 --> 00:36:08,160
most of their movement before they reach

1008
00:36:11,910 --> 00:36:10,560
the main sequence is vertical

1009
00:36:14,230 --> 00:36:11,920
they stay at roughly the same

1010
00:36:15,829 --> 00:36:14,240
temperature but they get less luminous

1011
00:36:17,750 --> 00:36:15,839
what's actually happening is that they

1012
00:36:20,790 --> 00:36:17,760
start kind of large and diffuse

1013
00:36:22,950 --> 00:36:20,800

and as time goes on gravity pulls them

1014
00:36:25,990 --> 00:36:22,960
together to make a more compact

1015
00:36:27,750 --> 00:36:26,000
object eventually reaching something the

1016
00:36:31,430 --> 00:36:27,760
size of the sun or like one of those red

1017
00:36:35,349 --> 00:36:33,910
and it takes them a few million years to

1018
00:36:36,630 --> 00:36:35,359
do this but then once they reach the

1019
00:36:38,230 --> 00:36:36,640
main sequence they stay there for

1020
00:36:39,430 --> 00:36:38,240
billions or perhaps even trillions of

1021
00:36:41,270 --> 00:36:39,440
years for some of the least massive

1022
00:36:44,790 --> 00:36:41,280
stars

1023
00:36:47,349 --> 00:36:44,800
solar masses

1024
00:36:49,109 --> 00:36:47,359
they mostly move horizontally across the

1025
00:36:50,870 --> 00:36:49,119
hr diagram as they form

1026
00:36:53,589 --> 00:36:50,880
and these stars everything they do they

1027
00:36:55,750 --> 00:36:53,599
do quickly at least for stars

1028
00:36:56,630 --> 00:36:55,760
they reach the main sequence almost

1029
00:36:59,349 --> 00:36:56,640
immediately

1030
00:37:00,950 --> 00:36:59,359
in star terms and they might spend only

1031
00:37:03,030 --> 00:37:00,960
a few million years on the main sequence

1032
00:37:04,390 --> 00:37:03,040
before evolving past that

1033
00:37:06,310 --> 00:37:04,400
so one of the challenges for the high

1034
00:37:09,030 --> 00:37:06,320
mass stars in ulysses

1035
00:37:10,550 --> 00:37:09,040
is to really get a good sample of stars

1036
00:37:11,829 --> 00:37:10,560
at all these different places in the hr

1037
00:37:13,910 --> 00:37:11,839
diagrams because

1038
00:37:15,589 --> 00:37:13,920

high mass stars are tricky and it's

1039
00:37:20,230 --> 00:37:15,599
difficult to predict what any given star

1040
00:37:23,990 --> 00:37:21,589
so i want to talk a little bit more

1041
00:37:25,750 --> 00:37:24,000
about the light that we get from stars

1042
00:37:27,109 --> 00:37:25,760
i've alluded to this a few times in the

1043
00:37:29,190 --> 00:37:27,119
talk so far but

1044
00:37:30,710 --> 00:37:29,200
beyond the visible parts of the spectrum

1045
00:37:32,230 --> 00:37:30,720
there's evidence for radiation that

1046
00:37:34,150 --> 00:37:32,240
can't be seen and this was

1047
00:37:36,950 --> 00:37:34,160
figured out not too long after people

1048
00:37:39,349 --> 00:37:36,960
started passing light through prisms

1049
00:37:41,510 --> 00:37:39,359
the ultraviolet rays are beyond violet

1050
00:37:43,109 --> 00:37:41,520
that's kind of what ultraviolet means

1051
00:37:45,109 --> 00:37:43,119
they were detected from the effect that

1052
00:37:46,230 --> 00:37:45,119
they had on the photographic technology

1053
00:37:48,950 --> 00:37:46,240
of the time

1054
00:37:50,790 --> 00:37:48,960
these uv rays would develop photographic

1055
00:37:51,750 --> 00:37:50,800
paper even more quickly than violators

1056
00:37:53,750 --> 00:37:51,760
themselves

1057
00:37:55,190 --> 00:37:53,760
so people knew there was there was

1058
00:37:57,030 --> 00:37:55,200
definitely radiation there even if they

1059
00:37:58,790 --> 00:37:57,040
couldn't see it

1060
00:38:00,550 --> 00:37:58,800
infrared rays were detected from their

1061
00:38:02,310 --> 00:38:00,560
effect on thermometers infrared

1062
00:38:04,950 --> 00:38:02,320
radiation would heat up thermometers

1063
00:38:08,150 --> 00:38:04,960

just like red light would

1064
00:38:09,829 --> 00:38:08,160
so this is how ultraviolet and infrared

1065
00:38:11,670 --> 00:38:09,839
radiation came to be known

1066
00:38:13,829 --> 00:38:11,680
and then there are also other well-known

1067
00:38:15,349 --> 00:38:13,839
kinds of electromagnetic radiation

1068
00:38:18,790 --> 00:38:15,359
you've probably heard of x-rays

1069
00:38:20,790 --> 00:38:18,800
radio waves gamma rays are another

1070
00:38:23,109 --> 00:38:20,800
and these are all fundamentally the same

1071
00:38:24,950 --> 00:38:23,119
thing just at different energies only a

1072
00:38:29,109 --> 00:38:24,960
small range of which can we see with our

1073
00:38:32,390 --> 00:38:30,550
so this little schematic shows what

1074
00:38:34,390 --> 00:38:32,400
happens to the different types of

1075
00:38:38,230 --> 00:38:34,400
electromagnetic radiation

1076
00:38:39,670 --> 00:38:38,240
as they reach earth's atmosphere

1077
00:38:42,550 --> 00:38:39,680
visible light makes it all the way

1078
00:38:44,790 --> 00:38:42,560
through to the ground unless it's cloudy

1079
00:38:46,470 --> 00:38:44,800
it's frustrating that with all the

1080
00:38:47,990 --> 00:38:46,480
technology we have after all these years

1081
00:38:49,109 --> 00:38:48,000
astronomers still can't do anything

1082
00:38:51,670 --> 00:38:49,119
about a cloudy night if they're

1083
00:38:53,430 --> 00:38:51,680
observing from the ground anyway

1084
00:38:54,870 --> 00:38:53,440
but without clouds that visible light

1085
00:38:56,550 --> 00:38:54,880
makes it all the way through to our

1086
00:38:58,950 --> 00:38:56,560
observatories

1087
00:39:00,710 --> 00:38:58,960
and uv light that's just a little bit

1088
00:39:02,230 --> 00:39:00,720

beyond visible and infrared light that's

1089
00:39:04,470 --> 00:39:02,240
just a little bit beyond visible can

1090
00:39:07,190 --> 00:39:04,480
also make it through

1091
00:39:08,550 --> 00:39:07,200
as you go further into the infrared you

1092
00:39:10,630 --> 00:39:08,560
reach a point where

1093
00:39:12,390 --> 00:39:10,640
the radiation this is kind of the

1094
00:39:14,069 --> 00:39:12,400
mid-infrared

1095
00:39:16,550 --> 00:39:14,079
doesn't quite reach the ground but it

1096
00:39:20,230 --> 00:39:16,560
does reach into the stratosphere

1097
00:39:22,550 --> 00:39:20,240
so we can use telescopes on planes

1098
00:39:24,950 --> 00:39:22,560
for example sofia the stratospheric

1099
00:39:27,349 --> 00:39:24,960
observatory for infrared astronomy

1100
00:39:29,109 --> 00:39:27,359
is a plane that takes off many nights a

1101
00:39:32,550 --> 00:39:29,119
year and goes up to 40 000

1102
00:39:33,990 --> 00:39:32,560
feet and detects infrared radiation

1103
00:39:35,829 --> 00:39:34,000
as you get into the far infrared you

1104
00:39:37,829 --> 00:39:35,839
really need space telescopes like the

1105
00:39:38,470 --> 00:39:37,839
spitzer and herschel space telescopes

1106
00:39:42,790 --> 00:39:38,480
that

1107
00:39:44,310 --> 00:39:42,800
recent decades

1108
00:39:46,710 --> 00:39:44,320
at very long wavelengths you start to

1109
00:39:48,470 --> 00:39:46,720
get into millimeter radio waves that do

1110
00:39:50,470 --> 00:39:48,480
reach through to the ground

1111
00:39:52,150 --> 00:39:50,480
and at very long wavelengths that's no

1112
00:39:55,589 --> 00:39:52,160
longer the case

1113
00:39:57,990 --> 00:39:55,599

going short of the visible the

1114
00:39:59,750 --> 00:39:58,000
ultraviolet ultraviolet gets through the

1115
00:40:01,750 --> 00:39:59,760
atmosphere to some extent

1116
00:40:03,030 --> 00:40:01,760
but then as you get to longer x-rays and

1117
00:40:04,870 --> 00:40:03,040
gamma rays light

1118
00:40:11,270 --> 00:40:04,880
no longer penetrates earth's atmosphere

1119
00:40:14,390 --> 00:40:11,280
and you need space telescopes

1120
00:40:16,150 --> 00:40:14,400
so ulysses is detecting

1121
00:40:19,589 --> 00:40:16,160
optical light as well but it's really

1122
00:40:21,190 --> 00:40:19,599
centered on ultraviolet spectroscopy

1123
00:40:23,430 --> 00:40:21,200
to measure ultraviolet wavelengths we

1124
00:40:25,270 --> 00:40:23,440
use a unit called the angstrom

1125
00:40:26,710 --> 00:40:25,280
it's not part of the international

1126
00:40:28,950 --> 00:40:26,720
system of units and

1127
00:40:30,150 --> 00:40:28,960
some physicists find this annoying that

1128
00:40:31,670 --> 00:40:30,160
astronomers use

1129
00:40:34,069 --> 00:40:31,680
something that's not officially part of

1130
00:40:36,790 --> 00:40:34,079
their of the system but an angstrom is

1131
00:40:39,190 --> 00:40:36,800
110 billionth of a meter

1132
00:40:41,030 --> 00:40:39,200
so pretty tiny the ultraviolet extends

1133
00:40:43,030 --> 00:40:41,040
from the extreme ultraviolet

1134
00:40:44,950 --> 00:40:43,040
at 100 angstroms out to the near

1135
00:40:48,390 --> 00:40:44,960
ultraviolet which is almost

1136
00:40:50,870 --> 00:40:48,400
visible at 4 000 angstroms

1137
00:40:51,750 --> 00:40:50,880
in this uv radiation it traces things

1138
00:40:53,750 --> 00:40:51,760

that are hot

1139
00:40:55,670 --> 00:40:53,760
if you remember when we looked at the

1140
00:40:57,109 --> 00:40:55,680
broad spectrum of a blue star

1141
00:40:59,430 --> 00:40:57,119
a lot of that light was actually coming

1142
00:41:02,550 --> 00:40:59,440
out in the uv so the hot stars eliminate

1143
00:41:06,150 --> 00:41:02,560
or give off a lot of uv

1144
00:41:08,790 --> 00:41:06,160
light it also traces energetic processes

1145
00:41:10,630 --> 00:41:08,800
low-mass stars may have energetic things

1146
00:41:13,030 --> 00:41:10,640
happening just above their surfaces

1147
00:41:18,470 --> 00:41:13,040
that give off uv emission so they can be

1148
00:41:21,510 --> 00:41:19,990
well as i was saying to study

1149
00:41:23,510 --> 00:41:21,520
ultraviolet light we really have to go

1150
00:41:24,710 --> 00:41:23,520
above the atmosphere

1151
00:41:26,630 --> 00:41:24,720
there are lots of different space

1152
00:41:28,710 --> 00:41:26,640
telescopes and there have been

1153
00:41:30,309 --> 00:41:28,720
ultraviolet telescopes before hubble but

1154
00:41:32,630 --> 00:41:30,319
at the present time hubble

1155
00:41:34,950 --> 00:41:32,640
is really the only way to do sensitive

1156
00:41:37,349 --> 00:41:34,960
ultraviolet spectroscopy

1157
00:41:38,790 --> 00:41:37,359
sort of you know it's not possible from

1158
00:41:39,829 --> 00:41:38,800
the ground and from space it's really

1159
00:41:41,990 --> 00:41:39,839
just hubble right now

1160
00:41:43,430 --> 00:41:42,000
there are alternatives in the works but

1161
00:41:45,670 --> 00:41:43,440
the only

1162
00:41:47,589 --> 00:41:45,680
you know the most promising of those

1163
00:41:48,630 --> 00:41:47,599

we're really waiting until the mid-2030s

1164
00:41:50,069 --> 00:41:48,640
to have anything that approaches

1165
00:41:51,349 --> 00:41:50,079
hubble's capabilities for uv

1166
00:41:54,470 --> 00:41:51,359
spectroscopy

1167
00:41:54,790 --> 00:41:54,480
so even here in this you know 30 years

1168
00:41:59,030 --> 00:41:54,800
in

1169
00:42:02,630 --> 00:41:59,040
make good use of its ultraviolet

1170
00:42:04,309 --> 00:42:02,640
spectroscopy capabilities to do science

1171
00:42:05,829 --> 00:42:04,319
now many of you probably know hubble has

1172
00:42:08,550 --> 00:42:05,839
multiple instruments it's got

1173
00:42:10,150 --> 00:42:08,560
wide field camera three and and the

1174
00:42:11,510 --> 00:42:10,160
advanced camera for surveys that do a

1175
00:42:14,710 --> 00:42:11,520
lot of imaging

1176
00:42:18,309 --> 00:42:14,720
but two of hubble's instruments have uv

1177
00:42:19,829 --> 00:42:18,319
spectres are able to do uv spectroscopy

1178
00:42:21,430 --> 00:42:19,839
and we're leaning on these heavily for

1179
00:42:24,950 --> 00:42:21,440
ulysses these are stis

1180
00:42:28,390 --> 00:42:27,190
stis is the space telescope imaging

1181
00:42:30,790 --> 00:42:28,400
spectrograph

1182
00:42:31,430 --> 00:42:30,800
this picture shows astronauts installing

1183
00:42:35,030 --> 00:42:31,440
stis

1184
00:42:36,309 --> 00:42:35,040
in 1997. and one of the real advantages

1185
00:42:38,470 --> 00:42:36,319
to hubble compared to other space

1186
00:42:39,750 --> 00:42:38,480
telescopes is it's in low earth orbit so

1187
00:42:43,109 --> 00:42:39,760
it's been possible

1188
00:42:43,990 --> 00:42:43,119

five times in its history for astronauts

1189
00:42:46,150 --> 00:42:44,000
to go up and

1190
00:42:47,910 --> 00:42:46,160
repair it and install new instruments

1191
00:42:49,270 --> 00:42:47,920
that's the major contributor to its

1192
00:42:51,829 --> 00:42:49,280
30-year lifetime

1193
00:42:52,550 --> 00:42:51,839
a lot of other space telescopes have

1194
00:42:54,390 --> 00:42:52,560
enabled

1195
00:42:55,910 --> 00:42:54,400
all sorts of wonderful science but

1196
00:42:58,150 --> 00:42:55,920
they're limited

1197
00:42:59,270 --> 00:42:58,160
you know for mechanical reasons limited

1198
00:43:02,630 --> 00:42:59,280
in some way

1199
00:43:06,390 --> 00:43:02,640
to operational lifetimes of 5 10

1200
00:43:10,550 --> 00:43:08,390
well the advantage to stis is not only

1201
00:43:12,470 --> 00:43:10,560
is it a uv spectrograph but it can also

1202
00:43:14,630 --> 00:43:12,480
obtain optical spectra

1203
00:43:16,150 --> 00:43:14,640
and infrared out a little bit into the

1204
00:43:17,349 --> 00:43:16,160
ir what we might call the very near

1205
00:43:18,950 --> 00:43:17,359
infrared

1206
00:43:20,550 --> 00:43:18,960
and it has a lot of different modes that

1207
00:43:22,150 --> 00:43:20,560
enable you to obtain different types of

1208
00:43:24,630 --> 00:43:22,160
spectra depending on what you're trying

1209
00:43:28,870 --> 00:43:24,640
to learn about your target of interest

1210
00:43:31,270 --> 00:43:28,880
so the best word for stis is versatile

1211
00:43:32,790 --> 00:43:31,280
our other instrument costs that's a

1212
00:43:35,190 --> 00:43:32,800
little bit newer than stis it was

1213
00:43:36,230 --> 00:43:35,200

installed in 2009 in the final servicing

1214
00:43:38,710 --> 00:43:36,240
mission

1215
00:43:39,510 --> 00:43:38,720
it obtains only ultraviolet spectra it

1216
00:43:41,190 --> 00:43:39,520
has a far

1217
00:43:42,870 --> 00:43:41,200
ultraviolet channel and a near

1218
00:43:45,670 --> 00:43:42,880
ultraviolet channel

1219
00:43:47,510 --> 00:43:45,680
but at higher sensitivity than stis so

1220
00:43:48,950 --> 00:43:47,520
if you have like focused ultraviolet

1221
00:43:52,829 --> 00:43:48,960
spectroscopy needs

1222
00:43:55,430 --> 00:43:52,839
often costs will be the ideal way to go

1223
00:43:57,349 --> 00:43:55,440
and you know like we like we

1224
00:43:59,190 --> 00:43:57,359
mentioned at the start of the talk i'm

1225
00:44:00,950 --> 00:43:59,200
on the cost team at the institute

1226
00:44:03,190 --> 00:44:00,960
all of the active hubble instruments

1227
00:44:04,470 --> 00:44:03,200
have teams of scientists and engineers

1228
00:44:05,270 --> 00:44:04,480
who work together to keep the

1229
00:44:08,630 --> 00:44:05,280
instruments well

1230
00:44:10,150 --> 00:44:08,640
calibrated we have lots of

1231
00:44:11,750 --> 00:44:10,160
lots of interesting ways of doing that

1232
00:44:13,750 --> 00:44:11,760
given that the instruments are all

1233
00:44:14,950 --> 00:44:13,760
in low earth orbit and we can't go

1234
00:44:16,950 --> 00:44:14,960
tinker with them

1235
00:44:18,550 --> 00:44:16,960
and we also have to support users to

1236
00:44:20,230 --> 00:44:18,560
help users of

1237
00:44:24,790 --> 00:44:20,240
hubble people who get hubble time make

1238
00:44:27,910 --> 00:44:26,710

so the ulysses project we talked about

1239
00:44:29,990 --> 00:44:27,920
this a little at the beginning but

1240
00:44:31,990 --> 00:44:30,000
that's starting to have been a while ago

1241
00:44:33,829 --> 00:44:32,000
so i'll remind you we use what's called

1242
00:44:35,589 --> 00:44:33,839
director's discretionary time

1243
00:44:36,870 --> 00:44:35,599
this was used in the past for programs

1244
00:44:39,190 --> 00:44:36,880
like the hubble deep field and the

1245
00:44:41,270 --> 00:44:39,200
frontier fields

1246
00:44:42,470 --> 00:44:41,280
ulysses is going to be about a thousand

1247
00:44:44,150 --> 00:44:42,480
orbits

1248
00:44:45,670 --> 00:44:44,160
unlike other observatories hubble

1249
00:44:48,150 --> 00:44:45,680
measures its time

1250
00:44:50,069 --> 00:44:48,160
not in hours but in orbits in an orbit

1251
00:44:51,510 --> 00:44:50,079
gives you 50 to 60 minutes of observing

1252
00:44:53,510 --> 00:44:51,520
time depending on where precisely you're

1253
00:44:56,069 --> 00:44:53,520
looking in the sky

1254
00:44:57,990 --> 00:44:56,079
half of the orbits are for massive stars

1255
00:44:59,589 --> 00:44:58,000
half of them are for low mass stars

1256
00:45:01,109 --> 00:44:59,599
and the thing about astronomers we like

1257
00:45:02,870 --> 00:45:01,119
to specialize so it's very different

1258
00:45:05,030 --> 00:45:02,880
communities of research that specialize

1259
00:45:07,030 --> 00:45:05,040
in each of these subfields

1260
00:45:08,309 --> 00:45:07,040
the data are immediately available to

1261
00:45:09,990 --> 00:45:08,319
the public

1262
00:45:11,990 --> 00:45:10,000
so if you were interested in high mass

1263
00:45:13,829 --> 00:45:12,000

stars you could go see which one hubble

1264
00:45:15,910 --> 00:45:13,839
was looking at this past week and go get

1265
00:45:17,589 --> 00:45:15,920
the data right away

1266
00:45:19,190 --> 00:45:17,599
and our staff play a lot of different

1267
00:45:21,750 --> 00:45:19,200
roles in ulysses

1268
00:45:22,870 --> 00:45:21,760
choosing targets setting up the hubble

1269
00:45:24,230 --> 00:45:22,880
observations and

1270
00:45:27,030 --> 00:45:24,240
making the data available to the

1271
00:45:29,349 --> 00:45:27,040
community in useful ways

1272
00:45:30,870 --> 00:45:29,359
so i just wanted to show you our team

1273
00:45:32,230 --> 00:45:30,880
that's implementing ulysses here at

1274
00:45:34,630 --> 00:45:32,240
space telescope

1275
00:45:36,230 --> 00:45:34,640
julia roman duvall is the the leader of

1276
00:45:39,270 --> 00:45:36,240
the implementation team

1277
00:45:40,950 --> 00:45:39,280
and joe taylor leads the data products

1278
00:45:41,430 --> 00:45:40,960
effort that's sort of what we do with

1279
00:45:43,030 --> 00:45:41,440
the data

1280
00:45:44,630 --> 00:45:43,040
after it's obtained to make it available

1281
00:45:47,510 --> 00:45:44,640
to the public

1282
00:45:49,670 --> 00:45:47,520
charles proffitt is the observing lead

1283
00:45:52,309 --> 00:45:49,680
so he leads the efforts to implement

1284
00:45:54,309 --> 00:45:52,319
the the observations and get everything

1285
00:45:56,309 --> 00:45:54,319
set up for the telescope

1286
00:45:58,390 --> 00:45:56,319
tala monroe helps him with that and then

1287
00:45:59,670 --> 00:45:58,400
we've got a whole staff of people that

1288
00:46:00,550 --> 00:45:59,680

help with different aspects of

1289
00:46:03,270 --> 00:46:00,560
implementation

1290
00:46:04,150 --> 00:46:03,280
and data products availability i'm sort

1291
00:46:07,589 --> 00:46:04,160
of

1292
00:46:09,190 --> 00:46:07,599
the leading up the scientific expertise

1293
00:46:10,870 --> 00:46:09,200
for the low mass young stars

1294
00:46:12,550 --> 00:46:10,880
alex fullerton handles the high mass

1295
00:46:14,069 --> 00:46:12,560
young stars and it's really just a

1296
00:46:16,230 --> 00:46:14,079
coordinated effort that crosses

1297
00:46:17,829 --> 00:46:16,240
different instrument teams and extends

1298
00:46:21,670 --> 00:46:17,839
into the office of public outreach lots

1299
00:46:26,309 --> 00:46:23,990
and we've got extensive involvement from

1300
00:46:27,670 --> 00:46:26,319
the broader community as well

1301
00:46:29,349 --> 00:46:27,680
there was the whole this whole thing

1302
00:46:31,190 --> 00:46:29,359
started with a commu a committee of 10

1303
00:46:31,829 --> 00:46:31,200
astronomers from europe asia and north

1304
00:46:34,069 --> 00:46:31,839
america

1305
00:46:35,990 --> 00:46:34,079
that sort of defined the broad goals of

1306
00:46:36,710 --> 00:46:36,000
the program and told us what to do with

1307
00:46:39,670 --> 00:46:36,720
our time

1308
00:46:41,109 --> 00:46:39,680
roughly speaking there was a call where

1309
00:46:43,109 --> 00:46:41,119
astronomers from anywhere

1310
00:46:45,349 --> 00:46:43,119
around the world could propose targets

1311
00:46:47,109 --> 00:46:45,359
as part of ulysses low mass and high

1312
00:46:48,870 --> 00:46:47,119
mass stars

1313
00:46:51,270 --> 00:46:48,880

we've got a science advisory committee

1314
00:46:53,589 --> 00:46:51,280
of eight astronomers who

1315
00:46:55,910 --> 00:46:53,599
give us input on on the work we're doing

1316
00:46:58,390 --> 00:46:55,920
and help us resolve issues on the fly

1317
00:47:00,390 --> 00:46:58,400
when scientific expertise is needed

1318
00:47:02,870 --> 00:47:00,400
and we've got huge international teams

1319
00:47:04,790 --> 00:47:02,880
of dozens of astronomers who are

1320
00:47:06,230 --> 00:47:04,800
you know getting funded to analyze some

1321
00:47:07,589 --> 00:47:06,240
of the ulysses data and to get

1322
00:47:08,550 --> 00:47:07,599
complementary data from other

1323
00:47:10,230 --> 00:47:08,560
observatories

1324
00:47:11,589 --> 00:47:10,240
we've got some snapshots here of some of

1325
00:47:13,349 --> 00:47:11,599
the ground-based and space-based

1326
00:47:14,230 --> 00:47:13,359
telescopes we'll be using alongside

1327
00:47:17,109 --> 00:47:14,240
hubble

1328
00:47:18,790 --> 00:47:17,119
nasa's infrared telescope facility

1329
00:47:20,150 --> 00:47:18,800
that's the one that i was

1330
00:47:21,670 --> 00:47:20,160
on the way to when i had to have

1331
00:47:23,030 --> 00:47:21,680
thanksgiving dinner at a gas station

1332
00:47:25,589 --> 00:47:23,040
that one time

1333
00:47:27,430 --> 00:47:25,599
there's europe's very large telescope

1334
00:47:29,109 --> 00:47:27,440
facility which is actually in chile but

1335
00:47:30,309 --> 00:47:29,119
just administered and operated by the

1336
00:47:32,870 --> 00:47:30,319
europeans

1337
00:47:33,910 --> 00:47:32,880
and nasa's chandra x-ray observatory

1338
00:47:36,870 --> 00:47:33,920

which has been up in

1339
00:47:41,349 --> 00:47:36,880
in space measuring x-rays from the sky

1340
00:47:45,589 --> 00:47:43,190
one aspect of ulysses that i've been

1341
00:47:48,870 --> 00:47:45,599
spending a lot of time on this past week

1342
00:47:51,510 --> 00:47:48,880
is this ground-based observing with this

1343
00:47:53,109 --> 00:47:51,520
robotic global telescope network which

1344
00:47:56,309 --> 00:47:53,119
is which is kind of interesting

1345
00:47:59,109 --> 00:47:56,319
just to see in operation

1346
00:48:01,589 --> 00:47:59,119
this uh world map here shows you where

1347
00:48:03,190 --> 00:48:01,599
this los cumbres global observatory has

1348
00:48:04,069 --> 00:48:03,200
all of its observing sites and these

1349
00:48:06,390 --> 00:48:04,079
aren't

1350
00:48:07,589 --> 00:48:06,400
really big telescopes necessarily but

1351
00:48:08,630 --> 00:48:07,599
there's a lot of them and they're well

1352
00:48:11,510 --> 00:48:08,640
positioned so as

1353
00:48:12,870 --> 00:48:11,520
earth rotates different telescopes are

1354
00:48:15,109 --> 00:48:12,880
always available to look at the night

1355
00:48:18,309 --> 00:48:15,119
sky

1356
00:48:20,309 --> 00:48:18,319
and we're using these to get some

1357
00:48:22,470 --> 00:48:20,319
data about the low-mass stars that put

1358
00:48:24,950 --> 00:48:22,480
their their ultraviolet observations in

1359
00:48:26,790 --> 00:48:24,960
context these stars are highly variable

1360
00:48:28,549 --> 00:48:26,800
so we want to observe them over and over

1361
00:48:29,910 --> 00:48:28,559
again understand how their brightness is

1362
00:48:32,630 --> 00:48:29,920
changing

1363
00:48:34,069 --> 00:48:32,640

both you know we we if and if one of

1364
00:48:35,829 --> 00:48:34,079
them were to suddenly get much brighter

1365
00:48:37,270 --> 00:48:35,839
it could damage costs or stiffs so we

1366
00:48:38,950 --> 00:48:37,280
want to prevent against that

1367
00:48:40,630 --> 00:48:38,960
but this also gives us good scientific

1368
00:48:41,109 --> 00:48:40,640
input to understand what these stars are

1369
00:48:42,950 --> 00:48:41,119
up to

1370
00:48:44,390 --> 00:48:42,960
when we look at them with hubble and

1371
00:48:45,910 --> 00:48:44,400
i've just kind of got some snapshots

1372
00:48:48,390 --> 00:48:45,920
here of some of the

1373
00:48:53,990 --> 00:48:48,400
relatively small 0.4 meter telescopes

1374
00:48:57,829 --> 00:48:56,230
so now on to the ultraviolet

1375
00:48:59,349 --> 00:48:57,839
spectroscopy that's at the heart of

1376
00:49:00,950 --> 00:48:59,359
ulysses

1377
00:49:04,309 --> 00:49:00,960
so why do we want to do ultraviolet

1378
00:49:06,390 --> 00:49:04,319
spectroscopy of young stars anyway

1379
00:49:08,630 --> 00:49:06,400
well i've got an image here from hubble

1380
00:49:10,870 --> 00:49:08,640
of the orion nebula

1381
00:49:12,790 --> 00:49:10,880
and orion is really important to

1382
00:49:14,870 --> 00:49:12,800
astronomers who study star formation

1383
00:49:15,990 --> 00:49:14,880
it's the closest star-forming region to

1384
00:49:18,069 --> 00:49:16,000
earth that has both

1385
00:49:19,829 --> 00:49:18,079
massive and low mass stars in large

1386
00:49:21,910 --> 00:49:19,839
quantities

1387
00:49:23,990 --> 00:49:21,920
the most massive stars in the orion

1388
00:49:26,870 --> 00:49:24,000

nebula are the trapezium in the center

1389
00:49:28,230 --> 00:49:26,880
and shown in this relatively large inset

1390
00:49:31,349 --> 00:49:28,240
here

1391
00:49:32,790 --> 00:49:31,359
these are o and b stars like i was

1392
00:49:35,670 --> 00:49:32,800
talking about

1393
00:49:38,710 --> 00:49:35,680
a while back and the radiation from

1394
00:49:40,549 --> 00:49:38,720
these stars which is mostly in the uv

1395
00:49:41,750 --> 00:49:40,559
impacts everything else that's going on

1396
00:49:44,309 --> 00:49:41,760
in the nebula

1397
00:49:46,230 --> 00:49:44,319
so they really control the evolution of

1398
00:49:46,950 --> 00:49:46,240
the orion nebula and the low-mass stars

1399
00:49:49,190 --> 00:49:46,960
within it

1400
00:49:51,910 --> 00:49:49,200
these smaller insets show you detailed

1401
00:49:54,069 --> 00:49:51,920
close-ups of some of the low-mass stars

1402
00:49:55,750 --> 00:49:54,079
and not all low-mass young stars are

1403
00:49:57,430 --> 00:49:55,760
like this but the ones in orion have

1404
00:50:00,950 --> 00:49:57,440
these kind of very carefully

1405
00:50:03,510 --> 00:50:00,960
shaped nebulae associated with them as

1406
00:50:03,990 --> 00:50:03,520
the uv light from those massive stars

1407
00:50:07,430 --> 00:50:04,000
kind of

1408
00:50:09,750 --> 00:50:07,440
shapes the environments of the stars

1409
00:50:11,829 --> 00:50:09,760
and then uv observations of the low-mass

1410
00:50:13,670 --> 00:50:11,839
stars themselves reveal high-energy

1411
00:50:14,390 --> 00:50:13,680
processes these stars are still forming

1412
00:50:17,670 --> 00:50:14,400
and that

1413
00:50:19,430 --> 00:50:17,680

that that gives off a lot of energy and

1414
00:50:24,230 --> 00:50:19,440
it gives it has a strong ultraviolet

1415
00:50:27,750 --> 00:50:26,069
so first i'll talk a little bit more

1416
00:50:29,589 --> 00:50:27,760
about the massive stars

1417
00:50:31,829 --> 00:50:29,599
the targets that we're observing with

1418
00:50:33,589 --> 00:50:31,839
ulysses that are massive are actually in

1419
00:50:35,750 --> 00:50:33,599
other galaxies

1420
00:50:36,630 --> 00:50:35,760
o and b type stars in the milky way are

1421
00:50:39,030 --> 00:50:36,640
often too

1422
00:50:40,390 --> 00:50:39,040
close and too bright to observe safely

1423
00:50:44,069 --> 00:50:40,400
with cos

1424
00:50:45,670 --> 00:50:44,079
and in stis's uv modes

1425
00:50:47,510 --> 00:50:45,680
so the massive stars we're looking at

1426
00:50:49,349 --> 00:50:47,520
most of them are in the large and small

1427
00:50:51,109 --> 00:50:49,359
magellanic clouds which are a few

1428
00:50:53,910 --> 00:50:51,119
hundred thousand light years away

1429
00:50:55,270 --> 00:50:53,920
a few of them are in these somewhat more

1430
00:50:57,109 --> 00:50:55,280
distant galaxies

1431
00:50:58,790 --> 00:50:57,119
still nearby as far as galaxies go but

1432
00:50:59,190 --> 00:50:58,800
they're four to five million light years

1433
00:51:03,030 --> 00:50:59,200
away

1434
00:51:05,270 --> 00:51:03,040
sexton's a and ngc 3109

1435
00:51:06,150 --> 00:51:05,280
an advantage to these galaxies is that

1436
00:51:10,150 --> 00:51:06,160
the stars

1437
00:51:12,069 --> 00:51:10,160
in them have fewer of those metals

1438
00:51:13,750 --> 00:51:12,079

you know anything heavier than helium

1439
00:51:15,190 --> 00:51:13,760
relative to the stars in our galaxy so

1440
00:51:17,430 --> 00:51:15,200
we can learn something about how

1441
00:51:18,390 --> 00:51:17,440
stars operate and how stellar evolution

1442
00:51:23,430 --> 00:51:18,400
proceeds

1443
00:51:27,109 --> 00:51:23,440
at what we call low metallicity

1444
00:51:29,109 --> 00:51:27,119
these are images from eso the european

1445
00:51:31,270 --> 00:51:29,119
southern observatory and hubble

1446
00:51:32,710 --> 00:51:31,280
of the four galaxies that have ulysses

1447
00:51:35,670 --> 00:51:32,720
massive stars in them

1448
00:51:36,390 --> 00:51:35,680
and you notice all of these galaxies are

1449
00:51:38,710 --> 00:51:36,400
a little bit

1450
00:51:40,790 --> 00:51:38,720
fuzzy and not quite as well organized as

1451
00:51:43,030 --> 00:51:40,800
the grand spirals that you see

1452
00:51:45,990 --> 00:51:43,040
in the milky way galaxy or the andromeda

1453
00:51:49,190 --> 00:51:48,470
so you know that this tells us something

1454
00:51:56,790 --> 00:51:49,200
about how

1455
00:52:00,790 --> 00:51:58,470
some sites of star formation in the

1456
00:52:02,710 --> 00:52:00,800
magellanic clouds are much more active

1457
00:52:05,109 --> 00:52:02,720
than those in our own galaxy so

1458
00:52:06,390 --> 00:52:05,119
again by observing stars in other

1459
00:52:08,309 --> 00:52:06,400
galaxies we

1460
00:52:09,510 --> 00:52:08,319
can sort of understand the full spectrum

1461
00:52:10,790 --> 00:52:09,520
of star formation

1462
00:52:13,270 --> 00:52:10,800
beyond just what you would see by

1463
00:52:16,069 --> 00:52:13,280

looking at orion or other regions

1464
00:52:17,589 --> 00:52:16,079
in our own galaxy this is a hubble image

1465
00:52:19,030 --> 00:52:17,599
of part of the tarantula nebula and the

1466
00:52:20,790 --> 00:52:19,040
large magellanic cloud some of our

1467
00:52:22,230 --> 00:52:20,800
ulysses targets are in the vicinity of

1468
00:52:23,030 --> 00:52:22,240
this region you can just look at how

1469
00:52:24,950 --> 00:52:23,040
many hot

1470
00:52:26,150 --> 00:52:24,960
bright blue stars there are packed into

1471
00:52:29,030 --> 00:52:26,160
a fairly small

1472
00:52:30,710 --> 00:52:29,040
region of space and again the radiation

1473
00:52:36,309 --> 00:52:30,720
from these stars really impacts the

1474
00:52:39,430 --> 00:52:38,710
this is the hubble 30th anniversary

1475
00:52:40,950 --> 00:52:39,440
image

1476
00:52:42,470 --> 00:52:40,960
which some of you may have seen in

1477
00:52:45,190 --> 00:52:42,480
recent months

1478
00:52:46,630 --> 00:52:45,200
and it's a really excellent image just

1479
00:52:48,870 --> 00:52:46,640
for its own sake

1480
00:52:51,030 --> 00:52:48,880
it's got this giant red nebula in the

1481
00:52:53,109 --> 00:52:51,040
large magellanic cloud and this smaller

1482
00:52:54,470 --> 00:52:53,119
blue nebula next to it but we notice

1483
00:52:55,349 --> 00:52:54,480
that one of our ulysses targets is

1484
00:52:58,870 --> 00:52:55,359
actually in it

1485
00:53:01,109 --> 00:52:58,880
this sk minus 67 167

1486
00:53:03,190 --> 00:53:01,119
circled there is one of the massive

1487
00:53:03,990 --> 00:53:03,200
ulysses stars and we'll have a spectrum

1488
00:53:05,750 --> 00:53:04,000

of it

1489
00:53:07,510 --> 00:53:05,760
and we like to use this to emphasize

1490
00:53:09,510 --> 00:53:07,520
that hubble's spectroscopic

1491
00:53:12,829 --> 00:53:09,520
investigations are just as important and

1492
00:53:15,589 --> 00:53:12,839
just as interesting as its imaging

1493
00:53:18,150 --> 00:53:15,599
observations

1494
00:53:19,190 --> 00:53:18,160
so we're about to look at a spectrum of

1495
00:53:21,670 --> 00:53:19,200
a hot star

1496
00:53:23,990 --> 00:53:21,680
and i just wanted to point out that when

1497
00:53:26,710 --> 00:53:24,000
astronomers analyze spectra

1498
00:53:28,549 --> 00:53:26,720
we tend not to look at these kind of

1499
00:53:29,109 --> 00:53:28,559
rainbow light plots with dark lines in

1500
00:53:33,349 --> 00:53:29,119
them

1501
00:53:36,470 --> 00:53:33,359
we instead show how the intensity

1502
00:53:39,190 --> 00:53:36,480
changes as a function of wavelength so

1503
00:53:39,910 --> 00:53:39,200
we'll look at a line like you see here

1504
00:53:42,950 --> 00:53:39,920
where you have

1505
00:53:44,870 --> 00:53:42,960
dips of different depths and widths for

1506
00:53:46,549 --> 00:53:44,880
different absorption lines

1507
00:53:49,109 --> 00:53:46,559
or possibly the reverse for emission

1508
00:53:51,190 --> 00:53:49,119
lines this is the spectrum of a hot star

1509
00:53:53,190 --> 00:53:51,200
about 20 000 degrees fahrenheit

1510
00:53:54,390 --> 00:53:53,200
an a-type star that's predominantly

1511
00:53:55,910 --> 00:53:54,400
hydrogen

1512
00:53:58,150 --> 00:53:55,920
and below that there's a spectrum of a

1513
00:54:00,630 --> 00:53:58,160

sun-like star about that with about the

1514
00:54:02,710 --> 00:54:00,640
10 000 degree temperature of our own sun

1515
00:54:06,309 --> 00:54:02,720
and many absorption lines due to metals

1516
00:54:10,630 --> 00:54:09,270
so this is a uv spectrum from costs of a

1517
00:54:11,990 --> 00:54:10,640
massive star

1518
00:54:13,829 --> 00:54:12,000
and you can see that there are lots of

1519
00:54:16,069 --> 00:54:13,839
absorption lines here a few things that

1520
00:54:18,069 --> 00:54:16,079
start to look like emission lines

1521
00:54:19,190 --> 00:54:18,079
and here are highlighted some lines that

1522
00:54:22,549 --> 00:54:19,200
are labeled as

1523
00:54:23,430 --> 00:54:22,559
ism this is a magnesium line stellar

1524
00:54:26,710 --> 00:54:23,440
wind

1525
00:54:29,109 --> 00:54:26,720
and cgm ism and cgm are the

1526
00:54:30,549 --> 00:54:29,119
interstellar medium the circum galactic

1527
00:54:32,710 --> 00:54:30,559
medium

1528
00:54:34,470 --> 00:54:32,720
and so that points to the fact that

1529
00:54:37,430 --> 00:54:34,480
these spectra tell you

1530
00:54:38,150 --> 00:54:37,440
not just about the star but about

1531
00:54:40,150 --> 00:54:38,160
interstellar

1532
00:54:43,910 --> 00:54:40,160
matter and intergalactic matter that

1533
00:54:47,990 --> 00:54:47,109
so this diagram shows how as light from

1534
00:54:51,430 --> 00:54:48,000
a star

1535
00:54:55,349 --> 00:54:51,440
passes through different clouds of gas

1536
00:54:58,069 --> 00:54:55,359
on the way to earth

1537
00:54:59,109 --> 00:54:58,079
those clouds can impart absorption lines

1538
00:55:01,030 --> 00:54:59,119

on the spectrum

1539
00:55:02,549 --> 00:55:01,040
so in addition to broad stellar lines

1540
00:55:03,349 --> 00:55:02,559
you might see narrow lines due to the

1541
00:55:04,549 --> 00:55:03,359
clouds

1542
00:55:06,789 --> 00:55:04,559
and you can learn something about the

1543
00:55:08,150 --> 00:55:06,799
composition of what

1544
00:55:10,549 --> 00:55:08,160
you might otherwise have thought to be

1545
00:55:12,309 --> 00:55:10,559
empty space so massive stars are very

1546
00:55:13,910 --> 00:55:12,319
useful in that sense

1547
00:55:15,910 --> 00:55:13,920
but the spectra also tell us a lot about

1548
00:55:18,549 --> 00:55:15,920
the stars themselves

1549
00:55:19,750 --> 00:55:18,559
this is a hubble image of the hot star

1550
00:55:22,470 --> 00:55:19,760
ada karani

1551
00:55:23,430 --> 00:55:22,480
it has this really intense stellar wind

1552
00:55:25,510 --> 00:55:23,440
it's

1553
00:55:26,470 --> 00:55:25,520
one of the most highly variable stars in

1554
00:55:28,150 --> 00:55:26,480
the sky

1555
00:55:29,750 --> 00:55:28,160
a bright source of uv light that

1556
00:55:31,270 --> 00:55:29,760
unfortunately is too bright for hubble

1557
00:55:32,390 --> 00:55:31,280
but it's a great example of a stellar

1558
00:55:35,430 --> 00:55:32,400
wind

1559
00:55:37,670 --> 00:55:35,440
when you see gas in front of a star it

1560
00:55:38,870 --> 00:55:37,680
gives us absorption lines just like

1561
00:55:41,510 --> 00:55:38,880
at the beginning of the talk i was

1562
00:55:43,270 --> 00:55:41,520
telling you about kirchhoff's laws

1563
00:55:45,510 --> 00:55:43,280

so you can see these broad absorption

1564
00:55:46,789 --> 00:55:45,520
lines from all that gas in front of us

1565
00:55:48,549 --> 00:55:46,799
and then they're blue shifted because

1566
00:55:50,390 --> 00:55:48,559
the gas is moving toward us

1567
00:55:52,470 --> 00:55:50,400
so this tells us something about the

1568
00:55:53,829 --> 00:55:52,480
velocity and the density structure of

1569
00:55:57,030 --> 00:55:53,839
that stellar wind

1570
00:55:58,950 --> 00:55:57,040
which ultimately is what's carving away

1571
00:56:00,829 --> 00:55:58,960
the nebulosity in the star forming

1572
00:56:04,870 --> 00:56:00,839
region and affecting the low mass young

1573
00:56:08,069 --> 00:56:06,230
now we're going to switch gears a little

1574
00:56:10,230 --> 00:56:08,079
bit and talk about the low-mass stars

1575
00:56:12,549 --> 00:56:10,240
themselves

1576
00:56:15,270 --> 00:56:12,559
the low-mass stars observed by ulysses

1577
00:56:17,670 --> 00:56:15,280
are nearby as far as stars go

1578
00:56:18,870 --> 00:56:17,680
there are hundreds or even just dozens

1579
00:56:20,710 --> 00:56:18,880
of light years away

1580
00:56:22,150 --> 00:56:20,720
as opposed to those massive stars which

1581
00:56:23,670 --> 00:56:22,160
were in some cases millions of light

1582
00:56:26,950 --> 00:56:23,680
years away

1583
00:56:27,670 --> 00:56:26,960
they're located in or very near dark

1584
00:56:29,589 --> 00:56:27,680
clouds

1585
00:56:31,190 --> 00:56:29,599
which are exactly what you would expect

1586
00:56:31,829 --> 00:56:31,200
from their name they're regions of gas

1587
00:56:33,589 --> 00:56:31,839
and dust

1588
00:56:35,510 --> 00:56:33,599

they're dense and therefore dark

1589
00:56:37,430 --> 00:56:35,520
compared to space in general

1590
00:56:38,950 --> 00:56:37,440
this is the stuff that's going on to

1591
00:56:40,309 --> 00:56:38,960
form new stars

1592
00:56:42,309 --> 00:56:40,319
and there are a couple images here of

1593
00:56:44,549 --> 00:56:42,319
the dark clouds chameleon 1

1594
00:56:47,430 --> 00:56:44,559
and lupus iii they get those names

1595
00:56:50,309 --> 00:56:47,440
because of the constellations they're in

1596
00:56:51,109 --> 00:56:50,319
so the ulysses low mass stars are also

1597
00:56:54,390 --> 00:56:51,119
known as t

1598
00:56:54,950 --> 00:56:54,400
tauri stars this is an image of t tauri

1599
00:56:57,109 --> 00:56:54,960
itself

1600
00:56:58,630 --> 00:56:57,119
it's it's not a ulysses target but it

1601
00:57:00,150 --> 00:56:58,640
gives its name to a class

1602
00:57:02,789 --> 00:57:00,160
the class of stars that we're studying

1603
00:57:04,390 --> 00:57:02,799
with ulysses

1604
00:57:06,470 --> 00:57:04,400
the name of this star means that it's a

1605
00:57:08,390 --> 00:57:06,480
variable star the single letter

1606
00:57:10,150 --> 00:57:08,400
t means that it was one of the first

1607
00:57:12,390 --> 00:57:10,160
variable stars to be discovered

1608
00:57:15,670 --> 00:57:12,400
in the constellation taurus which is

1609
00:57:17,589 --> 00:57:15,680
where you get the name tori

1610
00:57:20,549 --> 00:57:17,599
so the t tauri stars it was eventually

1611
00:57:22,950 --> 00:57:20,559
realized have masses similar to the suns

1612
00:57:24,470 --> 00:57:22,960
but instead of being a few billion years

1613
00:57:26,950 --> 00:57:24,480

old like the sun they're only a few

1614
00:57:28,870 --> 00:57:26,960
million years old they're basically the

1615
00:57:31,670 --> 00:57:28,880
unpredictable teenagers of

1616
00:57:32,870 --> 00:57:31,680
low mass stellar evolution they're still

1617
00:57:34,470 --> 00:57:32,880
building up mass

1618
00:57:36,390 --> 00:57:34,480
although not as quickly as they were

1619
00:57:38,230 --> 00:57:36,400
when they are infants

1620
00:57:40,150 --> 00:57:38,240
they're subject to unpredictable

1621
00:57:43,349 --> 00:57:40,160
outbursts at times as they

1622
00:57:46,470 --> 00:57:43,359
accrete matter and and emit some of it

1623
00:57:49,589 --> 00:57:46,480
and since mass determines how a star

1624
00:57:51,589 --> 00:57:49,599
evolves these are windows into the early

1625
00:57:52,230 --> 00:57:51,599
days of our own solar system we can get

1626
00:57:54,870 --> 00:57:52,240
a great

1627
00:57:55,750 --> 00:57:54,880
sense for what the sun and potentially

1628
00:57:57,910 --> 00:57:55,760
its planets

1629
00:58:01,829 --> 00:57:57,920
were up to only a million years after

1630
00:58:06,069 --> 00:58:03,430
here's a little schematic of how

1631
00:58:07,990 --> 00:58:06,079
low-mass star formation works

1632
00:58:10,630 --> 00:58:08,000
in those molecular clouds i was showing

1633
00:58:13,190 --> 00:58:10,640
you some portions of those clouds

1634
00:58:14,870 --> 00:58:13,200
are much denser than average and once

1635
00:58:16,390 --> 00:58:14,880
you get enough material in one place

1636
00:58:18,150 --> 00:58:16,400
it starts to collapse under its own

1637
00:58:20,150 --> 00:58:18,160
gravity so

1638
00:58:22,390 --> 00:58:20,160

you'll have collapse into what we call a

1639
00:58:25,190 --> 00:58:22,400
protostellar envelope

1640
00:58:28,549 --> 00:58:25,200
eventually something we call a protostar

1641
00:58:32,950 --> 00:58:28,559
forms in the center of that envelope

1642
00:58:36,069 --> 00:58:32,960
it has a disk forming around it and

1643
00:58:38,549 --> 00:58:36,079
jets emitted from the star start to

1644
00:58:39,430 --> 00:58:38,559
blow away parts of that envelope around

1645
00:58:40,630 --> 00:58:39,440
the poles

1646
00:58:41,910 --> 00:58:40,640
so if you're looking at it from just the

1647
00:58:43,589 --> 00:58:41,920
right angle you can start to see the

1648
00:58:45,030 --> 00:58:43,599
protostar and james webb is going to be

1649
00:58:47,270 --> 00:58:45,040
really useful for helping to understand

1650
00:58:49,030 --> 00:58:47,280
what these protostars are up to

1651
00:58:50,789 --> 00:58:49,040
ulysses is focused on slightly more

1652
00:58:52,630 --> 00:58:50,799
evolved stars where that envelope is

1653
00:58:55,589 --> 00:58:52,640
gone and you're left with a star

1654
00:58:57,349 --> 00:58:55,599
and a disk and probably planets forming

1655
00:58:59,349 --> 00:58:57,359
in the disk

1656
00:59:01,190 --> 00:58:59,359
after about two million years or maybe a

1657
00:59:01,990 --> 00:59:01,200
few million more years depending on the

1658
00:59:04,549 --> 00:59:02,000
star and

1659
00:59:06,390 --> 00:59:04,559
fine details of the situation even that

1660
00:59:10,630 --> 00:59:06,400
disc is gone you're left with the sun

1661
00:59:14,230 --> 00:59:12,150
and we know that t-tory stars are

1662
00:59:17,030 --> 00:59:14,240
forming planets

1663
00:59:18,309 --> 00:59:17,040

this is a artist's conception of the

1664
00:59:21,030 --> 00:59:18,319
alma observatory

1665
00:59:22,789 --> 00:59:21,040
in chile it's an array of telescopes way

1666
00:59:24,710 --> 00:59:22,799
up high in the atacama desert one of the

1667
00:59:26,150 --> 00:59:24,720
driest places on earth and it detects

1668
00:59:28,950 --> 00:59:26,160
millimeter wave radiation

1669
00:59:31,990 --> 00:59:28,960
so almost as low energy as radio waves

1670
00:59:34,549 --> 00:59:32,000
but not quite

1671
00:59:36,549 --> 00:59:34,559
as an array alma works as though it were

1672
00:59:38,950 --> 00:59:36,559
one giant telescope it doesn't have the

1673
00:59:40,710 --> 00:59:38,960
sensitivity of a huge telescope

1674
00:59:42,470 --> 00:59:40,720
that covers as much ground but it's got

1675
00:59:45,109 --> 00:59:42,480
the right angular resolution so it can

1676
00:59:48,150 --> 00:59:45,119
make really finely detailed images

1677
00:59:48,710 --> 00:59:48,160
and this is an image of hl tori which

1678
00:59:51,270 --> 00:59:48,720
like t

1679
00:59:51,990 --> 00:59:51,280
tauri is in the constellation taurus in

1680
00:59:55,430 --> 00:59:52,000
a variable

1681
00:59:57,270 --> 00:59:55,440
young star and in this image of the disc

1682
00:59:58,950 --> 00:59:57,280
you can see all this structure this came

1683
01:00:00,950 --> 00:59:58,960
out just about five years ago

1684
01:00:04,549 --> 01:00:00,960
and everybody was just amazed to see all

1685
01:00:06,630 --> 01:00:04,559
these gaps and rings in a disc

1686
01:00:08,549 --> 01:00:06,640
we don't have direct evidence for

1687
01:00:11,349 --> 01:00:08,559
planets in all disks like this

1688
01:00:12,950 --> 01:00:11,359

but those gaps and rings are pretty good

1689
01:00:15,910 --> 01:00:12,960
indirect evidence that planets are

1690
01:00:19,589 --> 01:00:17,750
now ulysses is not going to study the

1691
01:00:21,750 --> 01:00:19,599
details in these disks it studies what's

1692
01:00:23,750 --> 01:00:21,760
going on near the star

1693
01:00:25,430 --> 01:00:23,760
this is the uv invisible spectrum of a

1694
01:00:27,190 --> 01:00:25,440
t-tory star similar to what we'll be

1695
01:00:29,349 --> 01:00:27,200
getting with ulysses

1696
01:00:31,270 --> 01:00:29,359
so there's a lot going on here i want to

1697
01:00:33,589 --> 01:00:31,280
try to explain it all

1698
01:00:35,190 --> 01:00:33,599
we refer to the flattish part of the

1699
01:00:37,190 --> 01:00:35,200
spectrum that changes slowly with

1700
01:00:38,549 --> 01:00:37,200
wavelength as the continuum

1701
01:00:41,589 --> 01:00:38,559
and then we have all these bright

1702
01:00:43,990 --> 01:00:41,599
emission lines on top of it

1703
01:00:45,109 --> 01:00:44,000
in this image the red and the green

1704
01:00:47,349 --> 01:00:45,119
correspond

1705
01:00:49,430 --> 01:00:47,359
to visible light this will these will be

1706
01:00:52,069 --> 01:00:49,440
observed with stis

1707
01:00:55,349 --> 01:00:52,079
and in t tauri stars that visible light

1708
01:00:57,190 --> 01:00:55,359
is mostly coming from the star itself

1709
01:00:58,470 --> 01:00:57,200
as you go into shorter wavelengths the

1710
01:01:00,390 --> 01:00:58,480
uv continuum

1711
01:01:02,230 --> 01:01:00,400
the purple and blue that we'll be

1712
01:01:04,549 --> 01:01:02,240
observing with stiffs and then with cost

1713
01:01:06,309 --> 01:01:04,559

at the shortest wavelengths

1714
01:01:09,030 --> 01:01:06,319
the continuum that's available there is

1715
01:01:11,510 --> 01:01:09,040
mostly coming from accretion processes

1716
01:01:12,470 --> 01:01:11,520
as matter goes from the disc onto the

1717
01:01:16,309 --> 01:01:12,480
star

1718
01:01:18,549 --> 01:01:16,319
it emits a ton of energy

1719
01:01:20,150 --> 01:01:18,559
and that's what gives you a uv continuum

1720
01:01:21,510 --> 01:01:20,160
and then all of these emission lines

1721
01:01:23,190 --> 01:01:21,520
that you see at all these wavelengths

1722
01:01:25,510 --> 01:01:23,200
are also due to accretion

1723
01:01:26,950 --> 01:01:25,520
and in some cases the small fraction of

1724
01:01:28,470 --> 01:01:26,960
material that's being ejected from the

1725
01:01:30,470 --> 01:01:28,480
star

1726
01:01:31,829 --> 01:01:30,480
and these smaller plots here show you

1727
01:01:33,510 --> 01:01:31,839
how some of the far

1728
01:01:35,349 --> 01:01:33,520
ultraviolet lines look if you really

1729
01:01:37,030 --> 01:01:35,359
zoom in on them from the structure of

1730
01:01:38,789 --> 01:01:37,040
those lines you can learn a lot about

1731
01:01:41,109 --> 01:01:38,799
how material is moving just above the

1732
01:01:42,710 --> 01:01:41,119
surface of the star

1733
01:01:44,549 --> 01:01:42,720
now all of these t-tory stars are

1734
01:01:47,190 --> 01:01:44,559
recreating mass at

1735
01:01:47,829 --> 01:01:47,200
variable rates and one of the goals of

1736
01:01:50,230 --> 01:01:47,839
ulysses

1737
01:01:53,190 --> 01:01:50,240
is to study stars with a range of masses

1738
01:01:55,829 --> 01:01:53,200

and accretion rates so we can understand

1739
01:01:57,829 --> 01:01:55,839
how the star formation process depends

1740
01:02:00,309 --> 01:01:57,839
on those factors

1741
01:02:02,630 --> 01:02:00,319
whether massive stars form more quickly

1742
01:02:04,309 --> 01:02:02,640
than low-mass stars or

1743
01:02:07,029 --> 01:02:04,319
in just other aspects of the star

1744
01:02:10,150 --> 01:02:07,039
formation process

1745
01:02:13,510 --> 01:02:10,160
so from years of studying

1746
01:02:15,829 --> 01:02:13,520
spectra like this in uv and optical and

1747
01:02:19,109 --> 01:02:15,839
infrared wavelengths of t-tory stars

1748
01:02:20,549 --> 01:02:19,119
x-rays as well astronomers have

1749
01:02:22,390 --> 01:02:20,559
been able to put together this little

1750
01:02:24,069 --> 01:02:22,400
schematic of how accretion works in

1751
01:02:25,589 --> 01:02:24,079
low-mass young stars

1752
01:02:27,109 --> 01:02:25,599
and for me one of the most exciting

1753
01:02:28,710 --> 01:02:27,119
things about astronomy is

1754
01:02:31,029 --> 01:02:28,720
you can start with pretty indirect

1755
01:02:33,109 --> 01:02:31,039
evidence like a spectrum

1756
01:02:35,190 --> 01:02:33,119
and through detailed study and

1757
01:02:36,789 --> 01:02:35,200
theoretical modeling construct

1758
01:02:38,710 --> 01:02:36,799
a highly detailed picture of what's

1759
01:02:40,870 --> 01:02:38,720
going on in regions that are still far

1760
01:02:42,950 --> 01:02:40,880
too small to detect directly with an

1761
01:02:46,309 --> 01:02:42,960
imager

1762
01:02:49,829 --> 01:02:46,319
so in this t-tory star there's material

1763
01:02:51,270 --> 01:02:49,839

in its disk from just when it began to

1764
01:02:54,710 --> 01:02:51,280
form

1765
01:02:57,829 --> 01:02:54,720
and as you can see here

1766
01:03:00,150 --> 01:02:57,839
alma probes the outer disk

1767
01:03:03,349 --> 01:03:00,160
but then over time material in the disk

1768
01:03:04,950 --> 01:03:03,359
drifts inward

1769
01:03:07,190 --> 01:03:04,960
once it gets to the innermost part of

1770
01:03:09,190 --> 01:03:07,200
the disc which is what james webb will

1771
01:03:11,430 --> 01:03:09,200
excel in studying

1772
01:03:12,870 --> 01:03:11,440
it can't get any closer to the star by

1773
01:03:13,750 --> 01:03:12,880
continuing to move toward the star's

1774
01:03:15,109 --> 01:03:13,760
equator

1775
01:03:16,950 --> 01:03:15,119
the reason is that the star has a

1776
01:03:18,630 --> 01:03:16,960
magnetic field

1777
01:03:20,549 --> 01:03:18,640
this is another one of these things that

1778
01:03:22,230 --> 01:03:20,559
we can study from spectra that haven't

1779
01:03:23,829 --> 01:03:22,240
gone into much detail tonight but you

1780
01:03:26,630 --> 01:03:23,839
can learn about a star's magnetic field

1781
01:03:28,630 --> 01:03:26,640
from its spectra

1782
01:03:30,069 --> 01:03:28,640
so this disk material is encountering

1783
01:03:30,870 --> 01:03:30,079
resistance from the star's magnetic

1784
01:03:33,270 --> 01:03:30,880
field

1785
01:03:36,470 --> 01:03:33,280
and it has a much easier time flowing

1786
01:03:39,670 --> 01:03:36,480
along the star's magnetic field lines

1787
01:03:40,549 --> 01:03:39,680
where it then crashes into the star far

1788
01:03:43,990 --> 01:03:40,559

from its equator

1789
01:03:47,029 --> 01:03:44,000
closer to the poles so all this gas in

1790
01:03:49,750 --> 01:03:47,039
what we call this magnetospheric flow

1791
01:03:50,950 --> 01:03:49,760
is moving at high speeds and low density

1792
01:03:52,630 --> 01:03:50,960
and that's what gives us a lot of the

1793
01:03:55,029 --> 01:03:52,640
emission lines that we see in uv and

1794
01:03:56,789 --> 01:03:55,039
optical spectra

1795
01:03:58,390 --> 01:03:56,799
and then this heated region on the

1796
01:04:01,430 --> 01:03:58,400
stellar surface

1797
01:04:04,069 --> 01:04:01,440
you know the star itself is maybe 4 000

1798
01:04:04,950 --> 01:04:04,079
kelvin this accretion region gets much

1799
01:04:10,309 --> 01:04:04,960
hotter

1800
01:04:11,990 --> 01:04:10,319
directly underneath the accreting

1801
01:04:14,870 --> 01:04:12,000
material so

1802
01:04:17,270 --> 01:04:14,880
that radiation gives us the uv continuum

1803
01:04:19,910 --> 01:04:17,280
and even contributes to the x-rays

1804
01:04:20,390 --> 01:04:19,920
so hubble through ulysses is telling us

1805
01:04:23,430 --> 01:04:20,400
how

1806
01:04:25,349 --> 01:04:23,440
the accretion process works in t t-tory

1807
01:04:29,670 --> 01:04:25,359
stars with a broad range of masses and

1808
01:04:33,829 --> 01:04:32,069
so here's the timeline for ulysses and

1809
01:04:36,309 --> 01:04:33,839
our logo that was artfully contributed

1810
01:04:40,789 --> 01:04:36,319
by the office of public outreach

1811
01:04:42,309 --> 01:04:40,799
about 30 of 169 of the 169 massive stars

1812
01:04:44,150 --> 01:04:42,319
have already been observed

1813
01:04:46,789 --> 01:04:44,160

even in these other galaxies the massive

1814
01:04:49,829 --> 01:04:46,799
stars are fairly bright and it's

1815
01:04:51,109 --> 01:04:49,839
easy to observe a lot of them with the

1816
01:04:51,910 --> 01:04:51,119
amount of observing time we have

1817
01:04:55,190 --> 01:04:51,920
allocated

1818
01:04:56,549 --> 01:04:55,200
so that's already underway observations

1819
01:04:58,150 --> 01:04:56,559
of the low-mass stars are going to get

1820
01:04:59,750 --> 01:04:58,160
started in november

1821
01:05:00,870 --> 01:04:59,760
because these low-mass stars are so

1822
01:05:03,029 --> 01:05:00,880
variable there's all sorts of

1823
01:05:05,349 --> 01:05:03,039
coordinated observing going on

1824
01:05:06,789 --> 01:05:05,359
and in november there will be windows

1825
01:05:07,670 --> 01:05:06,799
where we can observe the stars at the

1826
01:05:09,349 --> 01:05:07,680
same time with

1827
01:05:11,109 --> 01:05:09,359
tess which is another another orbiting

1828
01:05:13,910 --> 01:05:11,119
telescope

1829
01:05:15,670 --> 01:05:13,920
so the t tauri stars the low mass stars

1830
01:05:17,670 --> 01:05:15,680
there are two samples there's a small

1831
01:05:19,589 --> 01:05:17,680
monitoring sample of just four stars

1832
01:05:20,390 --> 01:05:19,599
that are going to be observed over and

1833
01:05:22,150 --> 01:05:20,400
over again

1834
01:05:24,309 --> 01:05:22,160
to see how their uv spectra change with

1835
01:05:25,190 --> 01:05:24,319
time and then there's a much larger

1836
01:05:27,589 --> 01:05:25,200
survey sample

1837
01:05:29,109 --> 01:05:27,599
that will be observed one time each to

1838
01:05:31,270 --> 01:05:29,119

see how the spectra

1839
01:05:33,190 --> 01:05:31,280
depend on the masses of the different

1840
01:05:35,990 --> 01:05:33,200
stars in the survey sample

1841
01:05:37,750 --> 01:05:36,000
and their accretion rates observations

1842
01:05:38,870 --> 01:05:37,760
are going to be continuing through 2021

1843
01:05:40,710 --> 01:05:38,880
and 2022

1844
01:05:42,710 --> 01:05:40,720
so we still have another two or more

1845
01:05:44,069 --> 01:05:42,720
years of ulysses to go

1846
01:05:45,750 --> 01:05:44,079
we're currently getting ready for the

1847
01:05:47,829 --> 01:05:45,760
first data release

1848
01:05:50,390 --> 01:05:47,839
including not just data but tools for

1849
01:05:51,910 --> 01:05:50,400
inspecting and analyzing the data

1850
01:05:53,829 --> 01:05:51,920
and our office of public outreach is

1851
01:05:54,470 --> 01:05:53,839
developing materials to bring ulysses to

1852
01:05:56,710 --> 01:05:54,480
the public

1853
01:05:58,470 --> 01:05:56,720
and to disseminate our results to

1854
01:06:00,870 --> 01:05:58,480
astronomers as well

1855
01:06:03,109 --> 01:06:00,880
and just to conclude we're very excited

1856
01:06:05,190 --> 01:06:03,119
about making this new resource available

1857
01:06:06,630 --> 01:06:05,200
to astronomers but also to astronomy

1858
01:06:11,829 --> 01:06:06,640
enthusiasts like yourself

1859
01:06:18,470 --> 01:06:14,870
thank you will that was wonderful

1860
01:06:19,430 --> 01:06:18,480
it's a intense overview of what you have

1861
01:06:21,750 --> 01:06:19,440
to do

1862
01:06:23,510 --> 01:06:21,760
to unders not only understand all of the

1863
01:06:26,549 --> 01:06:23,520

background behind

1864
01:06:28,950 --> 01:06:26,559
ultraviolet spectroscopy but the in

1865
01:06:29,750 --> 01:06:28,960
in intense detail you've got to get to

1866
01:06:32,789 --> 01:06:29,760
to

1867
01:06:34,230 --> 01:06:32,799
accomplish a project like this this is

1868
01:06:37,670 --> 01:06:34,240
one of hubble's largest pro

1869
01:06:39,029 --> 01:06:37,680
programs ever right yes

1870
01:06:41,430 --> 01:06:39,039
a thousand orbits is a pretty huge

1871
01:06:43,109 --> 01:06:41,440
investment i mean uh candles was like

1872
01:06:45,589 --> 01:06:43,119
900 orbits right

1873
01:06:46,390 --> 01:06:45,599
and so this is and i thought that was

1874
01:06:48,150 --> 01:06:46,400
just you know

1875
01:06:50,069 --> 01:06:48,160
amazing that they got that much time for

1876
01:06:53,029 --> 01:06:50,079
candles um

1877
01:06:53,430 --> 01:06:53,039
so we had a couple questions online on

1878
01:06:56,230 --> 01:06:53,440
this

1879
01:06:58,230 --> 01:06:56,240
um but i wanted to take the as the host

1880
01:07:01,910 --> 01:06:58,240
to be able to ask you the first question

1881
01:07:03,750 --> 01:07:01,920
was um you talked about the

1882
01:07:05,349 --> 01:07:03,760
uh you made the great point when looking

1883
01:07:08,069 --> 01:07:05,359
at the cosmic reef that you know

1884
01:07:10,549 --> 01:07:08,079
hubble does imaging and it does spectra

1885
01:07:11,829 --> 01:07:10,559
and we've also we've we usually said the

1886
01:07:13,349 --> 01:07:11,839
office of public outreach that

1887
01:07:15,510 --> 01:07:13,359
you know about half of hubble's

1888
01:07:17,589 --> 01:07:15,520

observations are images and about half

1889
01:07:20,549 --> 01:07:17,599
are spectra do you have any um

1890
01:07:22,150 --> 01:07:20,559
any uh details on that whether that's

1891
01:07:23,829 --> 01:07:22,160
correct

1892
01:07:25,190 --> 01:07:23,839
um i don't know the exact breakdown i

1893
01:07:26,870 --> 01:07:25,200
think it might be a little bit more

1894
01:07:30,710 --> 01:07:26,880
weighted toward imaging

1895
01:07:33,589 --> 01:07:30,720
um but we certainly

1896
01:07:33,990 --> 01:07:33,599
you know the spectroscopy requires a lot

1897
01:07:37,109 --> 01:07:34,000
of

1898
01:07:38,069 --> 01:07:37,119
you know all the instrument teams are

1899
01:07:39,990 --> 01:07:38,079
working

1900
01:07:41,349 --> 01:07:40,000
about equally about equally hard on the

1901
01:07:43,589 --> 01:07:41,359
on the data that come in

1902
01:07:44,789 --> 01:07:43,599
right but i mean it just it's it's

1903
01:07:45,910 --> 01:07:44,799
really important for the public to

1904
01:07:47,910 --> 01:07:45,920
understand

1905
01:07:49,029 --> 01:07:47,920
just how much information we get from

1906
01:07:51,829 --> 01:07:49,039
spectra

1907
01:07:52,549 --> 01:07:51,839
and that you know it's it's equal in

1908
01:07:54,549 --> 01:07:52,559
partnership

1909
01:07:56,069 --> 01:07:54,559
to to imaging i mean everyone pays

1910
01:07:59,349 --> 01:07:56,079
attention to the beautiful

1911
01:08:00,870 --> 01:07:59,359
images but the the the information that

1912
01:08:01,589 --> 01:08:00,880
you gleaned which you talked about so

1913
01:08:04,630 --> 01:08:01,599

nicely

1914
01:08:08,789 --> 01:08:07,029
all right so now let's bring in grant

1915
01:08:11,109 --> 01:08:08,799
justice um

1916
01:08:12,390 --> 01:08:11,119
and grant has been monitoring the chat

1917
01:08:15,750 --> 01:08:12,400
online

1918
01:08:17,510 --> 01:08:15,760
and we he will be able to i assume he

1919
01:08:19,749 --> 01:08:17,520
has picked out a bunch of

1920
01:08:22,470 --> 01:08:19,759
of the most interesting questions to ask

1921
01:08:25,749 --> 01:08:22,480
us grant

1922
01:08:27,430 --> 01:08:25,759
hello yes we've actually had a

1923
01:08:29,030 --> 01:08:27,440
the chat's been very good today we

1924
01:08:29,829 --> 01:08:29,040
answered a lot of the questions ahead of

1925
01:08:32,470 --> 01:08:29,839
time

1926
01:08:34,470 --> 01:08:32,480
however uh i picked up a couple good

1927
01:08:35,110 --> 01:08:34,480
ones that i reserved before we sticked

1928
01:08:40,709 --> 01:08:35,120
frank and i

1929
01:08:43,990 --> 01:08:40,719
on them so um all right so

1930
01:08:46,870 --> 01:08:44,000
have any of the findings from the lhc

1931
01:08:49,590 --> 01:08:46,880
changed the essentials of astral

1932
01:08:53,030 --> 01:08:49,600
spectroscopy

1933
01:08:55,189 --> 01:08:53,040
the lhc the large hadron collider yeah

1934
01:08:56,550 --> 01:08:55,199
so when you're look like what i took

1935
01:08:58,630 --> 01:08:56,560
from this question was

1936
01:09:02,789 --> 01:08:58,640
when you're searching for elements when

1937
01:09:07,749 --> 01:09:05,110
are you searching for any elements

1938
01:09:09,590 --> 01:09:07,759

outside of your major ones do you look

1939
01:09:12,709 --> 01:09:09,600
for trace metals do you look

1940
01:09:14,630 --> 01:09:12,719
for that sort of thing and

1941
01:09:16,309 --> 01:09:14,640
if there were like what this person is

1942
01:09:16,950 --> 01:09:16,319
asking is are you looking for any of

1943
01:09:20,149 --> 01:09:16,960
them

1944
01:09:22,390 --> 01:09:20,159
the man-made or anything out of the

1945
01:09:24,390 --> 01:09:22,400
ordinary like not oxygen not hydrogen

1946
01:09:26,789 --> 01:09:24,400
not helium

1947
01:09:27,510 --> 01:09:26,799
there are especially in the most evolved

1948
01:09:30,070 --> 01:09:27,520
stars

1949
01:09:31,749 --> 01:09:30,080
there are elements that are pretty rare

1950
01:09:33,110 --> 01:09:31,759
in the universe

1951
01:09:35,590 --> 01:09:33,120
so people who are studying like red

1952
01:09:37,990 --> 01:09:35,600
supergiant stars and their winds

1953
01:09:39,030 --> 01:09:38,000
will detect elements in in trace

1954
01:09:41,030 --> 01:09:39,040
quantities

1955
01:09:42,390 --> 01:09:41,040
that you know we find just in trace

1956
01:09:43,829 --> 01:09:42,400
amounts here on earth as well

1957
01:09:45,590 --> 01:09:43,839
so it kind of gets it's starting to get

1958
01:09:48,070 --> 01:09:45,600
deeper into the into the

1959
01:09:50,070 --> 01:09:48,080
periodic table maybe not into those

1960
01:09:53,269 --> 01:09:50,080
bottom rows of things that we know

1961
01:09:57,350 --> 01:09:53,279
exclusively to be man-made

1962
01:10:01,189 --> 01:09:59,510
historical thing is that the element

1963
01:10:03,750 --> 01:10:01,199

helium was discovered

1964
01:10:05,030 --> 01:10:03,760
in the sun spectrum before we discovered

1965
01:10:07,910 --> 01:10:05,040
here on earth

1966
01:10:08,870 --> 01:10:07,920
so yeah we have looked into the spectra

1967
01:10:10,870 --> 01:10:08,880
of stars

1968
01:10:12,070 --> 01:10:10,880
and seen elements that we didn't

1969
01:10:14,070 --> 01:10:12,080
recognize

1970
01:10:16,229 --> 01:10:14,080
um and that's why it's called helium

1971
01:10:19,510 --> 01:10:16,239
helios meaning the sun

1972
01:10:22,709 --> 01:10:19,520
and that we discovered that before we

1973
01:10:24,470 --> 01:10:22,719
had had uh founded here on earth and i'm

1974
01:10:26,550 --> 01:10:24,480
getting a note from thomas uh will can

1975
01:10:29,669 --> 01:10:26,560
you stop your screen share so we can

1976
01:10:30,650 --> 01:10:29,679
bring the videos up okay i was just

1977
01:10:35,510 --> 01:10:30,660
about to say that

1978
01:10:39,590 --> 01:10:37,350
oh it looks like i got what trevor

1979
01:10:42,630 --> 01:10:39,600
wanted to ask so hey there we go

1980
01:10:45,110 --> 01:10:42,640
i'm trying to am i still

1981
01:10:47,110 --> 01:10:45,120
sharing uh yeah you have to go to the

1982
01:10:49,270 --> 01:10:47,120
same thing and hit the

1983
01:10:52,390 --> 01:10:49,280
the stop or at the top or it says stop

1984
01:10:55,430 --> 01:10:55,030
that seems to have disappeared uh do you

1985
01:10:58,950 --> 01:10:55,440
see

1986
01:11:02,070 --> 01:10:58,960
oh wait there we go there you go

1987
01:11:06,550 --> 01:11:02,080
all right cool

1988
01:11:10,070 --> 01:11:06,560

okay so i have a follow-up question here

1989
01:11:11,750 --> 01:11:10,080
um so going back to the graph

1990
01:11:13,430 --> 01:11:11,760
uh there are quite a few people who

1991
01:11:16,630 --> 01:11:13,440
wanted you to expand

1992
01:11:18,870 --> 01:11:16,640
a bit more on the actual spectrum that

1993
01:11:21,110 --> 01:11:18,880
you had up in one of your slides but

1994
01:11:22,630 --> 01:11:21,120
um how do you know if the black lines

1995
01:11:25,189 --> 01:11:22,640
that you see

1996
01:11:26,870 --> 01:11:25,199
the um that are are they caused by

1997
01:11:27,750 --> 01:11:26,880
something in the telescope's trajectory

1998
01:11:30,310 --> 01:11:27,760
are they caused by

1999
01:11:31,750 --> 01:11:30,320
atmosphere or something at the end point

2000
01:11:33,030 --> 01:11:31,760
how can you tell the difference in

2001
01:11:36,229 --> 01:11:33,040
something that's

2002
01:11:39,430 --> 01:11:36,239
uh

2003
01:11:41,030 --> 01:11:39,440
the destination or the focal point

2004
01:11:42,470 --> 01:11:41,040
that that can be tricky if we're looking

2005
01:11:43,990 --> 01:11:42,480
at a new type of object

2006
01:11:45,910 --> 01:11:44,000
it might there might be some debate

2007
01:11:48,310 --> 01:11:45,920
sometimes as to whether

2008
01:11:49,510 --> 01:11:48,320
something in the spectrum comes from you

2009
01:11:52,709 --> 01:11:49,520
know a star itself

2010
01:11:56,070 --> 01:11:52,719
or something in space along the way but

2011
01:11:57,270 --> 01:11:56,080
we've also come to know that certain

2012
01:12:00,070 --> 01:11:57,280
certain things are going to happen at

2013
01:12:02,070 --> 01:12:00,080

certain wavelengths routinely

2014
01:12:03,830 --> 01:12:02,080
for example i talked a lot about those

2015
01:12:05,990 --> 01:12:03,840
different hydrogen lines

2016
01:12:07,430 --> 01:12:06,000
in ultraviolet spectroscopy there's a

2017
01:12:10,390 --> 01:12:07,440
hydrogen line

2018
01:12:11,510 --> 01:12:10,400
it's got a wavelength of about 1200

2019
01:12:14,070 --> 01:12:11,520
angstroms

2020
01:12:15,510 --> 01:12:14,080
it happens to be about the same size as

2021
01:12:18,950 --> 01:12:15,520
one of these coronaviruses

2022
01:12:22,550 --> 01:12:18,960
this chance would have it but this

2023
01:12:25,669 --> 01:12:22,560
this line this hydrogen line is also

2024
01:12:28,550 --> 01:12:25,679
very bright in the earth's atmosphere

2025
01:12:31,189 --> 01:12:28,560
so it's tricky to observe this

2026
01:12:32,709 --> 01:12:31,199
particular hydrogen line in uv spectra

2027
01:12:34,550 --> 01:12:32,719
because we have this contribution from

2028
01:12:36,790 --> 01:12:34,560
the atmosphere

2029
01:12:38,950 --> 01:12:36,800
or in the infrared for example we have a

2030
01:12:40,229 --> 01:12:38,960
lot of absorption lines due to water in

2031
01:12:41,990 --> 01:12:40,239
the earth's atmosphere

2032
01:12:44,470 --> 01:12:42,000
so these are things that you know we see

2033
01:12:45,110 --> 01:12:44,480
repeatedly going back years looking at

2034
01:12:46,950 --> 01:12:45,120
anything in

2035
01:12:48,830 --> 01:12:46,960
space and we you know start to

2036
01:12:50,229 --> 01:12:48,840
understand what earth's atmosphere

2037
01:12:52,470 --> 01:12:50,239
contributes

2038
01:12:54,229 --> 01:12:52,480

and we come up with various clever ways

2039
01:12:58,950 --> 01:12:54,239
to remove that so we can see our signal

2040
01:13:02,390 --> 01:13:00,950
okay okay grant we have another question

2041
01:13:05,669 --> 01:13:02,400
from online

2042
01:13:07,910 --> 01:13:05,679
yep um this is actually an interesting

2043
01:13:10,229 --> 01:13:07,920
one

2044
01:13:13,510 --> 01:13:10,239
so i'm gonna take this and go a

2045
01:13:16,830 --> 01:13:15,990
yes we do have to add it to questions

2046
01:13:21,910 --> 01:13:16,840
yes

2047
01:13:24,790 --> 01:13:21,920
um how narrow of a band like

2048
01:13:27,110 --> 01:13:24,800
what um what kind of resolution can you

2049
01:13:29,110 --> 01:13:27,120
actually get out of spectroscopy down to

2050
01:13:30,950 --> 01:13:29,120
individual elements can you get down

2051
01:13:34,709 --> 01:13:30,960
further than that can you tell

2052
01:13:37,110 --> 01:13:34,719
like isotopes how and what is holding us

2053
01:13:40,310 --> 01:13:37,120
back from that right now

2054
01:13:41,510 --> 01:13:40,320
well this is really common in like the

2055
01:13:43,750 --> 01:13:41,520
astronomy that people are doing with

2056
01:13:45,910 --> 01:13:43,760
alma the millimeter array

2057
01:13:47,270 --> 01:13:45,920
where you can see kind of normal carbon

2058
01:13:49,990 --> 01:13:47,280
monoxide

2059
01:13:52,149 --> 01:13:50,000
it's not like a huge component of

2060
01:13:53,750 --> 01:13:52,159
protoplanetary disks but it gives a

2061
01:13:55,510 --> 01:13:53,760
strong spectral signature so people

2062
01:13:58,070 --> 01:13:55,520
often study carbon monoxide but then you

2063
01:14:00,790 --> 01:13:58,080

can have other isotopes like instead of

2064
01:14:02,709 --> 01:14:00,800
regular carbon you have a carbon with a

2065
01:14:04,229 --> 01:14:02,719
molecular weight of 13 so a slightly

2066
01:14:05,030 --> 01:14:04,239
heavier version of carbon paired with

2067
01:14:07,910 --> 01:14:05,040
oxygen

2068
01:14:10,149 --> 01:14:07,920
and that gives you line aligned at a

2069
01:14:12,149 --> 01:14:10,159
slightly different part of the spectrum

2070
01:14:13,350 --> 01:14:12,159
so in a lot of cases that's pretty well

2071
01:14:14,310 --> 01:14:13,360
understood we can look at these

2072
01:14:17,110 --> 01:14:14,320
different

2073
01:14:17,669 --> 01:14:17,120
isotope signatures to learn something

2074
01:14:19,030 --> 01:14:17,679
about

2075
01:14:20,470 --> 01:14:19,040
temperature and density that you

2076
01:14:23,270 --> 01:14:20,480
wouldn't have with just a single

2077
01:14:26,790 --> 01:14:25,830
all right so will you mentioned that you

2078
01:14:29,510 --> 01:14:26,800
know this is a

2079
01:14:30,870 --> 01:14:29,520
legacy program of hubble and that you

2080
01:14:31,750 --> 01:14:30,880
know i'm not sure the public truly

2081
01:14:33,990 --> 01:14:31,760
understands that

2082
01:14:36,229 --> 01:14:34,000
it comes to ultraviolet observations you

2083
01:14:37,669 --> 01:14:36,239
know spec hubble really is the

2084
01:14:39,510 --> 01:14:37,679
you know you have to be in space and

2085
01:14:40,310 --> 01:14:39,520
hubble is the game the biggest game in

2086
01:14:42,630 --> 01:14:40,320
town

2087
01:14:44,149 --> 01:14:42,640
uh how far into the future do we have to

2088
01:14:46,630 --> 01:14:44,159

look after hubble

2089
01:14:48,149 --> 01:14:46,640
unfortunately will go away how far do in

2090
01:14:48,870 --> 01:14:48,159
the future do we have to look to find

2091
01:14:51,669 --> 01:14:48,880
another

2092
01:14:53,110 --> 01:14:51,679
um ultraviolet uh observation capability

2093
01:14:56,229 --> 01:14:53,120
in space

2094
01:14:56,550 --> 01:14:56,239
well astronomers have a process for kind

2095
01:14:57,830 --> 01:14:56,560
of

2096
01:14:59,189 --> 01:14:57,840
getting together as a community and

2097
01:14:59,990 --> 01:14:59,199
deciding what kinds of missions they

2098
01:15:02,310 --> 01:15:00,000
want

2099
01:15:03,189 --> 01:15:02,320
and part of the process right now is

2100
01:15:06,630 --> 01:15:03,199
that there are

2101
01:15:08,390 --> 01:15:06,640
i think four large telescope missions

2102
01:15:09,669 --> 01:15:08,400
being advocated by different community

2103
01:15:11,910 --> 01:15:09,679
members

2104
01:15:13,590 --> 01:15:11,920
and you know there's a process by which

2105
01:15:15,350 --> 01:15:13,600
a decision will be made to maybe

2106
01:15:17,510 --> 01:15:15,360
maybe fund a fraction of those or just

2107
01:15:21,270 --> 01:15:17,520
one of them one of the ideas is called

2108
01:15:23,830 --> 01:15:21,280
luvoir it's the large ultraviolet

2109
01:15:25,350 --> 01:15:23,840
optical and ir telescope i don't think

2110
01:15:27,990 --> 01:15:25,360
it's a real french word but it kind of

2111
01:15:29,910 --> 01:15:28,000
sounds like one

2112
01:15:31,910 --> 01:15:29,920
we're excited about it either way so

2113
01:15:33,030 --> 01:15:31,920

right right and it's going to be a much

2114
01:15:36,229 --> 01:15:33,040
larger version

2115
01:15:38,550 --> 01:15:36,239
of hubble basically and

2116
01:15:39,669 --> 01:15:38,560
the idea is that this would be advocated

2117
01:15:42,550 --> 01:15:39,679
for

2118
01:15:43,750 --> 01:15:42,560
in what we call the decadal survey

2119
01:15:47,430 --> 01:15:43,760
that's being put together

2120
01:15:50,830 --> 01:15:47,440
now-ish and people talk about

2121
01:15:53,350 --> 01:15:50,840
you know it being the telescope of the

2122
01:15:56,070 --> 01:15:53,360
2030s so you know optimistically

2123
01:15:57,350 --> 01:15:56,080
maybe 2035 is when something like this

2124
01:16:00,149 --> 01:15:57,360
might get launched

2125
01:16:02,709 --> 01:16:00,159
so it's looking to be a while right so i

2126
01:16:05,110 --> 01:16:02,719
i guess that that truly emphasizes the

2127
01:16:06,630 --> 01:16:05,120
the legacy aspect of this amazing

2128
01:16:10,790 --> 01:16:06,640
project you're working on here

2129
01:16:12,550 --> 01:16:10,800
right right and well if

2130
01:16:14,229 --> 01:16:12,560
in addition to the hubble lifetime we on

2131
01:16:15,669 --> 01:16:14,239
costs are coming constantly coming up

2132
01:16:17,590 --> 01:16:15,679
with strategies to make the cost

2133
01:16:17,910 --> 01:16:17,600
detectors last as long as possible as

2134
01:16:19,990 --> 01:16:17,920
well

2135
01:16:21,990 --> 01:16:20,000
so we kind of think of it as our goal to

2136
01:16:25,350 --> 01:16:22,000
make costs last at least as long as hot

2137
01:16:26,870 --> 01:16:25,360
as hubble does that's a lucky goal

2138
01:16:28,070 --> 01:16:26,880

though

2139
01:16:30,070 --> 01:16:28,080
all right grant is that it for the

2140
01:16:32,470 --> 01:16:30,080
questions that's

2141
01:16:33,590 --> 01:16:32,480
that's it for the questions um i would

2142
01:16:36,390 --> 01:16:33,600
say though

2143
01:16:37,590 --> 01:16:36,400
uh if you wouldn't mind just for the

2144
01:16:40,070 --> 01:16:37,600
audience

2145
01:16:41,189 --> 01:16:40,080
because this was all about ulysses from

2146
01:16:44,149 --> 01:16:41,199
the beginning

2147
01:16:44,709 --> 01:16:44,159
um why don't you just give them a short

2148
01:16:51,830 --> 01:16:44,719
like

2149
01:16:53,750 --> 01:16:51,840
to hubble to sdsci because we talked

2150
01:16:58,390 --> 01:16:53,760
about everything all up here

2151
01:17:01,990 --> 01:17:00,550
well for me it's been a great

2152
01:17:04,790 --> 01:17:02,000
opportunity to work with people

2153
01:17:05,350 --> 01:17:04,800
all across the institute i mean just my

2154
01:17:08,229 --> 01:17:05,360
work with

2155
01:17:09,189 --> 01:17:08,239
with costs it's a team of maybe about 15

2156
01:17:11,110 --> 01:17:09,199
of us but

2157
01:17:12,229 --> 01:17:11,120
with ulysses we've got the stis team

2158
01:17:15,030 --> 01:17:12,239
involved

2159
01:17:17,910 --> 01:17:15,040
we have people from the mast archive

2160
01:17:19,350 --> 01:17:17,920
that archives all the hubble data

2161
01:17:21,590 --> 01:17:19,360
you know engineers scientists

2162
01:17:25,030 --> 01:17:21,600
technicians outreach staff

2163
01:17:26,950 --> 01:17:25,040

and it's it's really been great to

2164
01:17:28,229 --> 01:17:26,960
you know to have all that camaraderie

2165
01:17:29,750 --> 01:17:28,239
even though we're all working from

2166
01:17:32,630 --> 01:17:29,760
disparate locations across

2167
01:17:35,830 --> 01:17:32,640
baltimore and the greater you know in

2168
01:17:37,270 --> 01:17:35,840
the suburban maryland area

2169
01:17:39,189 --> 01:17:37,280
so you know for me that's that's the

2170
01:17:40,790 --> 01:17:39,199
best thing about it and one of the

2171
01:17:41,430 --> 01:17:40,800
things i love about projects like this

2172
01:17:43,030 --> 01:17:41,440
is that the

2173
01:17:44,470 --> 01:17:43,040
community input that you've gotten on

2174
01:17:46,630 --> 01:17:44,480
this but it's it's

2175
01:17:47,590 --> 01:17:46,640
it's not just you know sdsc i come up

2176
01:17:49,430 --> 01:17:47,600
with the ideas

2177
01:17:51,189 --> 01:17:49,440
it's you know bringing it out to the

2178
01:17:53,030 --> 01:17:51,199
whole astronomical community and they

2179
01:17:54,709 --> 01:17:53,040
get to participate in this

2180
01:17:56,630 --> 01:17:54,719
all right so will we want to thank you

2181
01:17:58,470 --> 01:17:56,640
again and you're getting tons of virtual

2182
01:18:00,870 --> 01:17:58,480
applause online

2183
01:18:01,750 --> 01:18:00,880
um i want to thank everyone for joining

2184
01:18:05,270 --> 01:18:01,760
us

2185
01:18:08,390 --> 01:18:05,280
we will be back next month on october

2186
01:18:10,149 --> 01:18:08,400
6th and you got to come join us because

2187
01:18:11,990 --> 01:18:10,159
uh you know you got these great projects

2188
01:18:15,189 --> 01:18:12,000

here with hubble but the

2189
01:18:17,669 --> 01:18:15,199
next wide field infrared space telescope

2190
01:18:19,510 --> 01:18:17,679
will be called the roman space telescope

2191
01:18:20,229 --> 01:18:19,520
and you will hear about it from some

2192
01:18:22,149 --> 01:18:20,239
experts

2193
01:18:23,830 --> 01:18:22,159
who are having a conference here at uh

2194
01:18:25,590 --> 01:18:23,840
uh well actually i guess a virtual

2195
01:18:27,590 --> 01:18:25,600
conference at space telescope

2196
01:18:29,030 --> 01:18:27,600
and they've just selected two great

2197
01:18:30,550 --> 01:18:29,040
experts to come talk to you about the

2198
01:18:32,870 --> 01:18:30,560
roman space telescope