PUBLIC LECTURE SERIES

Hubble from Space and Integral-field Spectroscopy from the Ground

Featuring Guest Speaker:

Marc Sarzi

1
00:00:08,629 --> 00:00:06,789
hello and welcome to the space telescope

2
00:00:09,830 --> 00:00:08,639
public lecture series

3
00:00:12,310 --> 00:00:09,840
tonight

4
00:00:14,310 --> 00:00:12,320
hubble from space an integral field

5
00:00:17,750 --> 00:00:14,320
spectroscopy from the ground

6
00:00:20,710 --> 00:00:17,760
seeing both the forest and the trees

7
00:00:23,670 --> 00:00:20,720
by dr mark sarsi of the arma observatory

8
00:00:26,070 --> 00:00:23,680
and planetarium

9
00:00:27,750 --> 00:00:26,080
i'm your host dr frank summers of the

10
00:00:30,150 --> 00:00:27,760
office of public outreach here at the

11
00:00:31,750 --> 00:00:30,160
space telescope science institute in

12
00:00:34,310 --> 00:00:31,760
baltimore maryland

13
00:00:36,389 --> 00:00:34,320

and as always i want to give special

14
00:00:38,470 --> 00:00:36,399
thanks to this tech team and i call them

15
00:00:41,670 --> 00:00:38,480
amazing every month but they really are

16
00:00:44,069 --> 00:00:41,680
amazing thomas marufu and grant justice

17
00:00:47,029 --> 00:00:44,079
who do the webcasting recording and get

18
00:00:49,190 --> 00:00:47,039
it out to you on youtube

19
00:00:51,750 --> 00:00:49,200
our upcoming talks

20
00:00:53,670 --> 00:00:51,760
next month another real

21
00:00:55,990 --> 00:00:53,680
sort of

22
00:00:58,389 --> 00:00:56,000
deviation from our norm we're going to

23
00:01:00,310 --> 00:00:58,399
go into neutrino astronomy

24
00:01:02,470 --> 00:01:00,320
all right uh how do you know that you

25
00:01:05,030 --> 00:01:02,480
can do astronomy with neutrinos well if

26
00:01:07,429 --> 00:01:05,040
you don't well venge definitely show up

27
00:01:10,070 --> 00:01:07,439
in april where marco santander of the

28
00:01:13,109 --> 00:01:10,080
university of alabama will tell you how

29
00:01:16,550 --> 00:01:13,119
you can do astronomy with neutrinos

30
00:01:19,670 --> 00:01:16,560
on may 3rd the nebulous effects of

31
00:01:21,190 --> 00:01:19,680
supernova imposter syndrome a title

32
00:01:24,550 --> 00:01:21,200
that's probably trying to be a little

33
00:01:26,149 --> 00:01:24,560
bit too clever but um it's by this guy

34
00:01:28,149 --> 00:01:26,159
frank stummers you know who has the same

35
00:01:30,630 --> 00:01:28,159
name as me so he's probably just trying

36
00:01:33,990 --> 00:01:30,640
to be clever for this stuff uh what he's

37
00:01:37,910 --> 00:01:34,000
actually talking about uh is eta carne

38
00:01:42,069 --> 00:01:37,920

um a supernova imposter that due to its

39
00:01:44,389 --> 00:01:42,079
uh uh its explosion created a nebula

40
00:01:47,670 --> 00:01:44,399
in june we will have understanding the

41
00:01:49,910 --> 00:01:47,680
formation and evolution of galaxies by a

42
00:01:51,590 --> 00:01:49,920
wonderful speaker cameron hummels from

43
00:01:53,670 --> 00:01:51,600
caltech

44
00:01:56,310 --> 00:01:53,680
you want to find out about these uh

45
00:01:57,469 --> 00:01:56,320
talks and more go to our website which

46
00:02:01,270 --> 00:01:57,479
you can find at

47
00:02:04,069 --> 00:02:01,280
stsci.edu public hyphen lectures

48
00:02:05,510 --> 00:02:04,079
you will have pointers to our webcasts

49
00:02:07,990 --> 00:02:05,520
as well as

50
00:02:10,790 --> 00:02:08,000
the easiest way to subscribe to our

51
00:02:13,830 --> 00:02:12,550
there are a list of our upcoming

52
00:02:18,070 --> 00:02:13,840
lectures

53
00:02:19,830 --> 00:02:18,080
get the full information about it

54
00:02:22,070 --> 00:02:19,840
including the the speaker title and

55
00:02:25,350 --> 00:02:22,080
description but also after it has been

56
00:02:28,790 --> 00:02:25,360
recorded the links to the stsci webcast

57
00:02:31,190 --> 00:02:28,800
as well as the webcast on youtube

58
00:02:32,229 --> 00:02:31,200
our email list well the announcements as

59
00:02:33,990 --> 00:02:32,239
i said

60
00:02:35,110 --> 00:02:34,000
easiest to sign up on webs on the

61
00:02:37,430 --> 00:02:35,120
website

62
00:02:39,150 --> 00:02:37,440
as an alternative you can also subscribe

63
00:02:42,229 --> 00:02:39,160

to our youtube channel

64
00:02:44,470 --> 00:02:42,239
youtube.com hubble space telescope all

65
00:02:47,030 --> 00:02:44,480
one word hubble space telescope and you

66
00:02:50,550 --> 00:02:47,040
will get notices of our new videos as

67
00:02:52,390 --> 00:02:50,560
well as reminders of these live events

68
00:02:54,070 --> 00:02:52,400
as always if you have comments or

69
00:02:59,110 --> 00:02:54,080
questions you can send them to the email

70
00:03:03,670 --> 00:03:01,430
our social media accounts are for the

71
00:03:05,750 --> 00:03:03,680
hubble space telescope the webspace

72
00:03:07,830 --> 00:03:05,760
telescope and for the space telescope

73
00:03:10,710 --> 00:03:07,840
science institute and they're available

74
00:03:11,830 --> 00:03:10,720
on facebook twitter youtube and

75
00:03:14,309 --> 00:03:11,840
instagram

76
00:03:16,710 --> 00:03:14,319
i myself only do a tiny amount of social

77
00:03:21,270 --> 00:03:16,720
media and i'm confined me as dr frank

78
00:03:25,509 --> 00:03:23,509
the news from the universe for march

79
00:03:28,070 --> 00:03:25,519
2022

80
00:03:30,309 --> 00:03:28,080
our first story as it has been the last

81
00:03:33,430 --> 00:03:30,319
couple of months is an update for the

82
00:03:36,869 --> 00:03:33,440
web space telescope this month it's

83
00:03:39,990 --> 00:03:36,879
seeing stars and taking selfies

84
00:03:41,990 --> 00:03:40,000
so last month we talked about the web

85
00:03:44,710 --> 00:03:42,000
getting out to the second lagrangian

86
00:03:46,789 --> 00:03:44,720
point or as we call it l2

87
00:03:48,710 --> 00:03:46,799
this diagram shows you the five

88
00:03:51,270 --> 00:03:48,720

lagrangian points and these are

89
00:03:53,589 --> 00:03:51,280
gravitational semi-stable points between

90
00:03:56,149 --> 00:03:53,599
the sun and the gravity of the sun and

91
00:03:58,630 --> 00:03:56,159
the earth and you can see that the l2 is

92
00:03:59,670 --> 00:03:58,640
on the far side of the sun of earth from

93
00:04:01,589 --> 00:03:59,680
the sun

94
00:04:03,990 --> 00:04:01,599
so that those sun shields can always

95
00:04:05,750 --> 00:04:04,000
block the light of the sun as well as

96
00:04:07,030 --> 00:04:05,760
the light of earth and the moon that

97
00:04:08,309 --> 00:04:07,040
might interfere with infrared

98
00:04:11,670 --> 00:04:08,319
observations

99
00:04:15,589 --> 00:04:11,680
so it's now out at l2 but it takes about

100
00:04:17,670 --> 00:04:15,599
six months at l2 in order to commission

101
00:04:20,710 --> 00:04:17,680
it and and test it so what are we doing

102
00:04:25,110 --> 00:04:20,720
for testing well we're looking at stars

103
00:04:26,870 --> 00:04:25,120
and this is a picture of one star

104
00:04:28,710 --> 00:04:26,880
but it's one star

105
00:04:30,790 --> 00:04:28,720
18 times

106
00:04:34,070 --> 00:04:30,800
as you may remember there are 18

107
00:04:36,550 --> 00:04:34,080
different mirror segments on web

108
00:04:38,550 --> 00:04:36,560
and to take this picture they had to a

109
00:04:41,110 --> 00:04:38,560
lot they had to align the telescope so

110
00:04:42,950 --> 00:04:41,120
that the star was in each mirror

111
00:04:45,350 --> 00:04:42,960
successively okay so this isn't just one

112
00:04:48,070 --> 00:04:45,360
picture this is 18 pictures co-added

113
00:04:50,710 --> 00:04:48,080

together to show where the initial

114
00:04:52,230 --> 00:04:50,720
alignment of the mirrors is and you know

115
00:04:53,909 --> 00:04:52,240
this looks like it's ratty and all over

116
00:04:56,710 --> 00:04:53,919
the place but actually this is really

117
00:04:58,550 --> 00:04:56,720
good because the field of view that they

118
00:05:01,110 --> 00:04:58,560
needed to take to ensure that they got

119
00:05:02,629 --> 00:05:01,120
it was about four or five times larger

120
00:05:04,310 --> 00:05:02,639
than this so it's actually that these

121
00:05:06,629 --> 00:05:04,320
are all quite tied together this is

122
00:05:08,629 --> 00:05:06,639
actually a success okay

123
00:05:12,230 --> 00:05:08,639
and then they had to identify which

124
00:05:13,830 --> 00:05:12,240
segments got which image all right

125
00:05:16,950 --> 00:05:13,840
and you can see that they mult have the

126
00:05:19,029 --> 00:05:16,960
segments in the a b and c uh things and

127
00:05:20,230 --> 00:05:19,039
in the wings etc and they give them the

128
00:05:22,950 --> 00:05:20,240
numbers okay

129
00:05:24,950 --> 00:05:22,960
now how did they figure out which image

130
00:05:27,189 --> 00:05:24,960
was from which mirror

131
00:05:27,990 --> 00:05:27,199
well that's where the selfie cam comes

132
00:05:30,710 --> 00:05:28,000
in

133
00:05:32,710 --> 00:05:30,720
and so this is an image from an

134
00:05:34,629 --> 00:05:32,720
engineering camera we're going to give

135
00:05:37,430 --> 00:05:34,639
it the nickname the selfie camera but

136
00:05:39,749 --> 00:05:37,440
it's really an engineering camera that

137
00:05:41,830 --> 00:05:39,759
looks at the secondary mirror

138
00:05:43,909 --> 00:05:41,840

so that they can figure out what's going

139
00:05:46,150 --> 00:05:43,919
on with the primary mirror so this

140
00:05:48,150 --> 00:05:46,160
really is a sort of little selfie right

141
00:05:50,150 --> 00:05:48,160
using the secondary mirror as sort of a

142
00:05:51,430 --> 00:05:50,160
big long selfie stick to look at the

143
00:05:54,070 --> 00:05:51,440
primary mirror

144
00:05:56,870 --> 00:05:54,080
now you can see one of these segments in

145
00:05:58,790 --> 00:05:56,880
web is bright that's the one that has

146
00:06:01,670 --> 00:05:58,800
the star in it at this point for this

147
00:06:03,749 --> 00:06:01,680
observation right and by doing this 18

148
00:06:04,550 --> 00:06:03,759
times and you know taking the image and

149
00:06:06,629 --> 00:06:04,560
seeing

150
00:06:08,550 --> 00:06:06,639
which mirror they've got it in to get it

151
00:06:09,990 --> 00:06:08,560
right or actually probably figure out

152
00:06:11,430 --> 00:06:10,000
get it in the mirror and then take the

153
00:06:13,909 --> 00:06:11,440
image right

154
00:06:15,670 --> 00:06:13,919
they can figure out which segment

155
00:06:17,029 --> 00:06:15,680
corresponds to which image in that

156
00:06:18,950 --> 00:06:17,039
mosaic

157
00:06:21,990 --> 00:06:18,960
then they can organize them

158
00:06:24,950 --> 00:06:22,000
according to the layout of the mirrors

159
00:06:27,029 --> 00:06:24,960
this is the initial image of that star

160
00:06:29,189 --> 00:06:27,039
from the 18 mirrors without adjusting

161
00:06:30,710 --> 00:06:29,199
the mirrors one bit okay and you can see

162
00:06:32,150 --> 00:06:30,720
now this is really ratty this is all

163
00:06:33,590 --> 00:06:32,160

over the place okay

164
00:06:35,270 --> 00:06:33,600
so the next thing they're going to do

165
00:06:37,029 --> 00:06:35,280
they're going to align the segments do

166
00:06:39,590 --> 00:06:37,039
the large scale alignments of the

167
00:06:42,309 --> 00:06:39,600
segments to make those stars look better

168
00:06:44,550 --> 00:06:42,319
all right and so the next step

169
00:06:45,830 --> 00:06:44,560
they go through and they do the large

170
00:06:47,830 --> 00:06:45,840
scale

171
00:06:49,510 --> 00:06:47,840
segment alignment to make those stars

172
00:06:51,430 --> 00:06:49,520
look relatively good no this is not

173
00:06:53,510 --> 00:06:51,440
perfect this is not nowhere near

174
00:06:55,270 --> 00:06:53,520
finished okay it's just the initial

175
00:06:57,110 --> 00:06:55,280
large scale alignment

176
00:07:00,629 --> 00:06:57,120
all right and then they can take those

177
00:07:02,710 --> 00:07:00,639
18 and pull them all together to image

178
00:07:05,189 --> 00:07:02,720
stack and create

179
00:07:08,309 --> 00:07:05,199
the point spread function all right so

180
00:07:10,629 --> 00:07:08,319
this is all 18 mirror segment

181
00:07:13,189 --> 00:07:10,639
images of those stars together in one

182
00:07:15,510 --> 00:07:13,199
and i'm going to blow this up for you

183
00:07:17,909 --> 00:07:15,520
that's what a very very bright star

184
00:07:20,150 --> 00:07:17,919
looks like in the initial

185
00:07:21,670 --> 00:07:20,160
mirror alignment for web

186
00:07:23,670 --> 00:07:21,680
okay and i'm going to bring up the

187
00:07:26,070 --> 00:07:23,680
hubble point spread function as a

188
00:07:28,150 --> 00:07:26,080

comparison so on the left we've got the

189
00:07:30,550 --> 00:07:28,160
hubble point spread function for a very

190
00:07:32,790 --> 00:07:30,560
bright star and on the right we've got

191
00:07:35,110 --> 00:07:32,800
just the initial point spread function

192
00:07:36,870 --> 00:07:35,120
for web for a bright star

193
00:07:38,550 --> 00:07:36,880
and you can see how much cleaner hubble

194
00:07:40,950 --> 00:07:38,560
is but that's the goal that's where

195
00:07:42,950 --> 00:07:40,960
we're headed but the other thing is that

196
00:07:45,749 --> 00:07:42,960
we're so used to the hubble you know the

197
00:07:47,830 --> 00:07:45,759
cross shaped uh point spread function

198
00:07:49,510 --> 00:07:47,840
with web we've got hexagonal mirrors

199
00:07:52,230 --> 00:07:49,520
we've got the design we're actually

200
00:07:53,990 --> 00:07:52,240
going to get a six pointed star for the

201
00:07:55,510 --> 00:07:54,000
point spread function as well as you can

202
00:07:56,950 --> 00:07:55,520
see there's a little detector bleed i

203
00:07:59,510 --> 00:07:56,960
think that's detector bleed along the

204
00:08:01,830 --> 00:07:59,520
axis or maybe we get an eight-pointed

205
00:08:03,909 --> 00:08:01,840
star i'm not quite sure i'm learning as

206
00:08:04,869 --> 00:08:03,919
we go just as you are

207
00:08:07,029 --> 00:08:04,879
but

208
00:08:08,790 --> 00:08:07,039
you can see where web is now they've got

209
00:08:10,710 --> 00:08:08,800
an initial bright star point spread

210
00:08:13,270 --> 00:08:10,720
function and over the next couple months

211
00:08:15,350 --> 00:08:13,280
they're going to continue to do all

212
00:08:17,510 --> 00:08:15,360
small scale refinements to each of those

213
00:08:19,350 --> 00:08:17,520

individual 18 mirror segments and align

214
00:08:20,629 --> 00:08:19,360
them so that they get something as clean

215
00:08:22,710 --> 00:08:20,639
and beautiful

216
00:08:26,230 --> 00:08:22,720
as we see on the left in the hubble

217
00:08:33,029 --> 00:08:30,150
our second story uh arp 143 and the

218
00:08:34,630 --> 00:08:33,039
giant space triangle that almost sounds

219
00:08:37,190 --> 00:08:34,640
like a children's story let me tell you

220
00:08:39,029 --> 00:08:37,200
about the giants but no um what we're

221
00:08:42,709 --> 00:08:39,039
really talking about

222
00:08:45,110 --> 00:08:42,719
is the arp atlas of peculiar galaxies

223
00:08:47,750 --> 00:08:45,120
all right now that word peculiar means

224
00:08:50,070 --> 00:08:47,760
that they've got strange shapes and

225
00:08:52,310 --> 00:08:50,080
halton ark created this big catalog of

226
00:08:55,110 --> 00:08:52,320
lots and lots of strangely shaped

227
00:08:57,430 --> 00:08:55,120
galaxies this is not his atlas this is

228
00:08:59,509 --> 00:08:57,440
actually a book about his atlas because

229
00:09:01,190 --> 00:08:59,519
they kind of make some really cool

230
00:09:02,230 --> 00:09:01,200
shapes and they're really really quite

231
00:09:05,110 --> 00:09:02,240
beautiful

232
00:09:06,870 --> 00:09:05,120
so hubble has observed a bunch of these

233
00:09:08,550 --> 00:09:06,880
armed galaxies okay and they're pairs of

234
00:09:11,190 --> 00:09:08,560
galaxies that have stretched each other

235
00:09:12,870 --> 00:09:11,200
apart and some of them have some some

236
00:09:17,350 --> 00:09:12,880
very fun shapes

237
00:09:20,230 --> 00:09:17,360
so for example this one this is arp 147

238
00:09:23,269 --> 00:09:20,240

and it was when we released in our press

239
00:09:24,949 --> 00:09:23,279
package referred to as a perfect 10

240
00:09:27,030 --> 00:09:24,959
because you can see this galaxy on the

241
00:09:29,269 --> 00:09:27,040
left looks like a one and the galaxy on

242
00:09:31,350 --> 00:09:29,279
the right looks like a zero

243
00:09:33,670 --> 00:09:31,360
in truth of course these galaxies are

244
00:09:34,949 --> 00:09:33,680
you know distorted each other uh in

245
00:09:36,470 --> 00:09:34,959
terms of their gravitational

246
00:09:38,790 --> 00:09:36,480
interactions

247
00:09:39,750 --> 00:09:38,800
another one and a really classic one we

248
00:09:43,750 --> 00:09:39,760
released

249
00:09:46,070 --> 00:09:43,760
was called the rose this is arp 273

250
00:09:48,550 --> 00:09:46,080
and you can see how this top galaxy here

251
00:09:51,110 --> 00:09:48,560
forms the rose and the bottom galaxy

252
00:09:53,350 --> 00:09:51,120
here forms the stem and this was a very

253
00:09:55,190 --> 00:09:53,360
beautiful uh thing that we released but

254
00:09:56,790 --> 00:09:55,200
i gotta say that we actually turned this

255
00:09:58,630 --> 00:09:56,800
image on its side

256
00:10:01,030 --> 00:09:58,640
um and a whole bunch of us said hey you

257
00:10:02,389 --> 00:10:01,040
know what this this stem galaxy actually

258
00:10:03,670 --> 00:10:02,399
looks kind of like a hummingbird from

259
00:10:05,590 --> 00:10:03,680
this perspective

260
00:10:08,790 --> 00:10:05,600
so we got a lot of interesting

261
00:10:09,670 --> 00:10:08,800
interpretations and one of my favorites

262
00:10:11,910 --> 00:10:09,680
okay

263
00:10:14,470 --> 00:10:11,920

is arp 142

264
00:10:17,190 --> 00:10:14,480
um and this was nicknamed the penguin

265
00:10:20,150 --> 00:10:17,200
and egg galaxy and i hope you can see

266
00:10:22,710 --> 00:10:20,160
the uh idea of the penguin up here um

267
00:10:24,710 --> 00:10:22,720
and the egg down here i'm sure this is

268
00:10:27,030 --> 00:10:24,720
after somebody saw march of the penguins

269
00:10:29,269 --> 00:10:27,040
and said oh this looks just like that so

270
00:10:30,829 --> 00:10:29,279
what have we got to add to that well we

271
00:10:32,630 --> 00:10:30,839
actually have arp

272
00:10:34,710 --> 00:10:32,640
143

273
00:10:37,350 --> 00:10:34,720
and as the title of the story tells you

274
00:10:39,030 --> 00:10:37,360
it's got a giant space

275
00:10:43,110 --> 00:10:39,040
triangle

276
00:10:44,870 --> 00:10:43,120
astronomy you get circles you get ovals

277
00:10:48,310 --> 00:10:44,880
you get big stretched out linear things

278
00:10:50,230 --> 00:10:48,320
but triangles what's going on here

279
00:10:52,550 --> 00:10:50,240
well you can see that this brownish

280
00:10:55,750 --> 00:10:52,560
galaxy over here on the left

281
00:10:56,870 --> 00:10:55,760
is its gravity is pulling on this

282
00:10:59,670 --> 00:10:56,880
blueish

283
00:11:01,590 --> 00:10:59,680
galaxy over here all right and so these

284
00:11:03,829 --> 00:11:01,600
pair of galaxies are interacting and the

285
00:11:05,910 --> 00:11:03,839
gravity is pulling on this stuff you

286
00:11:07,990 --> 00:11:05,920
know galaxies are not solid objects okay

287
00:11:09,829 --> 00:11:08,000
they are clouds of gas and dust and

288
00:11:12,069 --> 00:11:09,839

stars and those clouds get pulled and

289
00:11:15,590 --> 00:11:12,079
you can really see this beautiful

290
00:11:17,350 --> 00:11:15,600
stretching out of the blue stars here

291
00:11:19,509 --> 00:11:17,360
and all the other thing that you can see

292
00:11:21,110 --> 00:11:19,519
is that in that gravity gravitational

293
00:11:23,030 --> 00:11:21,120
interaction

294
00:11:25,269 --> 00:11:23,040
it's almost assuredly that this star

295
00:11:27,030 --> 00:11:25,279
formation all this blue stuff all these

296
00:11:29,269 --> 00:11:27,040
newborn stars

297
00:11:31,670 --> 00:11:29,279
were triggered by the gravitational

298
00:11:33,350 --> 00:11:31,680
interaction between these two galaxies

299
00:11:35,030 --> 00:11:33,360
now i can't prove that but you know

300
00:11:37,430 --> 00:11:35,040
that's generally a lot of what happens

301
00:11:39,110 --> 00:11:37,440
when you see interacting galaxies the

302
00:11:40,550 --> 00:11:39,120
gas clouds are

303
00:11:42,630 --> 00:11:40,560
stretched and distorted and they

304
00:11:45,110 --> 00:11:42,640
collapse and then you do get these

305
00:11:47,670 --> 00:11:45,120
bursts of star formation so this is

306
00:11:49,590 --> 00:11:47,680
actually it looks looks like to me a

307
00:11:51,110 --> 00:11:49,600
star bursting galaxy because there's

308
00:11:52,710 --> 00:11:51,120
just been a tremendous amount of star

309
00:11:55,030 --> 00:11:52,720
formation recently

310
00:11:56,389 --> 00:11:55,040
probably due to the interaction

311
00:11:58,230 --> 00:11:56,399
and the fact that it creates this

312
00:12:01,269 --> 00:11:58,240
triangle is that it was probably

313
00:12:03,670 --> 00:12:01,279

relatively circular but the taffy pull

314
00:12:05,509 --> 00:12:03,680
of the gravity pulling the stuff out

315
00:12:06,949 --> 00:12:05,519
makes it into this really interesting

316
00:12:10,629 --> 00:12:06,959
triangle shape

317
00:12:17,509 --> 00:12:10,639
so that uh is our latest arp galaxy for

318
00:12:23,030 --> 00:12:20,629
our speaker tonight uh we'll be talking

319
00:12:26,389 --> 00:12:23,040
about hubble from space and integral

320
00:12:29,910 --> 00:12:26,399
field spectroscopy from the ground

321
00:12:33,269 --> 00:12:29,920
this is dr mark sarzy and we're very

322
00:12:36,629 --> 00:12:33,279
excited to have him he is our first

323
00:12:39,350 --> 00:12:36,639
presenter from europe uh he is actually

324
00:12:40,550 --> 00:12:39,360
coming to us from arma in northern

325
00:12:41,750 --> 00:12:40,560
ireland

326
00:12:43,110 --> 00:12:41,760
and

327
00:12:45,509 --> 00:12:43,120
he will be uh

328
00:12:47,190 --> 00:12:45,519
to present his talk and it's wonderful

329
00:12:50,550 --> 00:12:47,200
because i was able to recruit him over

330
00:12:52,870 --> 00:12:50,560
the internet um and be able to get

331
00:12:54,470 --> 00:12:52,880
international speakers come in and talk

332
00:12:56,949 --> 00:12:54,480
uh mark would you please turn on your

333
00:12:58,870 --> 00:12:56,959
video and start your screen share

334
00:13:01,350 --> 00:12:58,880
there we go

335
00:13:03,110 --> 00:13:01,360
mark uh tells me that the arma

336
00:13:04,230 --> 00:13:03,120
observatory which is over his left

337
00:13:06,150 --> 00:13:04,240
shoulder

338
00:13:08,870 --> 00:13:06,160

is the home of where the new general

339
00:13:11,750 --> 00:13:08,880
catalog known as the mgc catalog to

340
00:13:13,910 --> 00:13:11,760
the cognoscenti uh was actually taken uh

341
00:13:16,230 --> 00:13:13,920
and defined at arma

342
00:13:17,590 --> 00:13:16,240
he started his career in italy uh in

343
00:13:19,509 --> 00:13:17,600
padua

344
00:13:21,829 --> 00:13:19,519
and did his undergraduate and some of

345
00:13:24,470 --> 00:13:21,839
his graduate work there he also did some

346
00:13:26,310 --> 00:13:24,480
of his graduate work at the max planck

347
00:13:28,870 --> 00:13:26,320
in heidelberg

348
00:13:31,190 --> 00:13:28,880
working on supermassive black holes

349
00:13:32,870 --> 00:13:31,200
he then decided to take a tour of the

350
00:13:37,030 --> 00:13:32,880
united kingdom

351
00:13:40,310 --> 00:13:37,040
doing work at durham and in oxford and

352
00:13:42,710 --> 00:13:40,320
before settling down in arma

353
00:13:45,590 --> 00:13:42,720
so we're excited to have him here and

354
00:13:47,750 --> 00:13:45,600
he tells me that he is a big gamer

355
00:13:50,230 --> 00:13:47,760
and no that's not a big game hunter or

356
00:13:53,910 --> 00:13:50,240
it's no it's not an online video gamer

357
00:13:57,590 --> 00:13:53,920
he's actually one of the table top gamer

358
00:14:01,509 --> 00:13:57,600
folks and he loves the tolkien games so

359
00:14:03,829 --> 00:14:01,519
ladies and gentlemen dr mark sarzy

360
00:14:05,030 --> 00:14:03,839
thank you frank for the introduction

361
00:14:10,790 --> 00:14:05,040
i'll

362
00:14:14,829 --> 00:14:12,550
can you share my screen can you see my

363
00:14:18,069 --> 00:14:14,839

screen frank

364
00:14:19,030 --> 00:14:18,079
yep all right

365
00:14:22,629 --> 00:14:19,040
let me

366
00:14:25,509 --> 00:14:22,639
cut the beginning of my presentation

367
00:14:26,870 --> 00:14:25,519
and start my presentation

368
00:14:28,470 --> 00:14:26,880
everything looks good

369
00:14:31,430 --> 00:14:28,480
okay

370
00:14:33,030 --> 00:14:31,440
so as frank says today i'm going to try

371
00:14:34,870 --> 00:14:33,040
to talk to you a bit about integral

372
00:14:38,150 --> 00:14:34,880
field spectroscopy which

373
00:14:40,629 --> 00:14:38,160
um it's a very important tool

374
00:14:43,590 --> 00:14:40,639
that has been added to the arsenal of

375
00:14:45,750 --> 00:14:43,600
astronomers in the last say 20 years

376
00:14:48,389 --> 00:14:45,760
to better understand

377
00:14:51,189 --> 00:14:48,399
in particular the fuzzy and diffused

378
00:14:53,670 --> 00:14:51,199
objects in the sky

379
00:14:56,470 --> 00:14:53,680
which is also

380
00:14:58,389 --> 00:14:56,480
was also the the focus of

381
00:15:01,030 --> 00:14:58,399
the research here in arma

382
00:15:03,590 --> 00:15:01,040
200 years ago almost

383
00:15:05,990 --> 00:15:03,600
when indeed the ngc catalogue was

384
00:15:07,990 --> 00:15:06,000
compiled at the time where people did

385
00:15:10,550 --> 00:15:08,000
not know the difference between nebulae

386
00:15:14,069 --> 00:15:10,560
and galaxies that was only

387
00:15:15,990 --> 00:15:14,079
figured out later um and indeed is

388
00:15:17,750 --> 00:15:16,000

because of integrity of spectroscopy we

389
00:15:20,710 --> 00:15:17,760
can we could really do a great advances

390
00:15:23,910 --> 00:15:20,720
in the understanding of diffuse nebulae

391
00:15:25,910 --> 00:15:23,920
and galaxies and clusters

392
00:15:28,230 --> 00:15:25,920
and so what i wanted to try to do today

393
00:15:30,949 --> 00:15:28,240
was to actually see what was the synergy

394
00:15:33,269 --> 00:15:30,959
of uh integral field spectroscopy and

395
00:15:36,710 --> 00:15:33,279
apple space telescope observation since

396
00:15:38,550 --> 00:15:36,720
i am actually your guest tonight

397
00:15:40,790 --> 00:15:38,560
so

398
00:15:42,949 --> 00:15:40,800
i first need to introduce you about

399
00:15:44,150 --> 00:15:42,959
integral spectroscopy and spectroscopy

400
00:15:45,829 --> 00:15:44,160
at all

401
00:15:47,430 --> 00:15:45,839
so what i'm going to do i'm going to

402
00:15:48,949 --> 00:15:47,440
just

403
00:15:51,350 --> 00:15:48,959
basically give a little word about

404
00:15:54,150 --> 00:15:51,360
spectroscopy so in essence what is

405
00:15:57,509 --> 00:15:54,160
spectroscopy is basically the process of

406
00:16:00,069 --> 00:15:57,519
splitting light in its uh

407
00:16:01,749 --> 00:16:00,079
simple components colors if you want and

408
00:16:04,550 --> 00:16:01,759
different wavelengths

409
00:16:06,949 --> 00:16:04,560
typically this is achieved the prism you

410
00:16:08,389 --> 00:16:06,959
may be familiar with the natural prism

411
00:16:09,509 --> 00:16:08,399
that are actually

412
00:16:11,670 --> 00:16:09,519
droplets

413
00:16:14,389 --> 00:16:11,680

in our atmosphere when we

414
00:16:15,829 --> 00:16:14,399
these droplets create a rainbow

415
00:16:18,069 --> 00:16:15,839
in the sky

416
00:16:20,069 --> 00:16:18,079
and prism on the other end is something

417
00:16:22,629 --> 00:16:20,079
that was more

418
00:16:24,790 --> 00:16:22,639
studied uh at the time of newton in

419
00:16:26,470 --> 00:16:24,800
particular who actually demonstrated the

420
00:16:28,310 --> 00:16:26,480
very nature of light

421
00:16:30,389 --> 00:16:28,320
at a time in fact when people thought

422
00:16:33,430 --> 00:16:30,399
that prison these very interesting funny

423
00:16:35,430 --> 00:16:33,440
objects were actually coloring light

424
00:16:37,670 --> 00:16:35,440
rather than splitting light and newton

425
00:16:39,350 --> 00:16:37,680
could demonstrate that that was actually

426
00:16:42,310 --> 00:16:39,360
what this prism was doing because by

427
00:16:44,710 --> 00:16:42,320
putting another prism after one prism it

428
00:16:46,949 --> 00:16:44,720
could actually recombine the rainbow

429
00:16:49,670 --> 00:16:46,959
back into white light

430
00:16:52,790 --> 00:16:49,680
and nowadays spectroscopy

431
00:16:55,350 --> 00:16:52,800
is a process where we try to understand

432
00:16:57,990 --> 00:16:55,360
the nature of particular features in the

433
00:16:59,430 --> 00:16:58,000
spectra of the light

434
00:17:01,749 --> 00:16:59,440
that comes from

435
00:17:03,350 --> 00:17:01,759
different sources and that has become

436
00:17:04,390 --> 00:17:03,360
particularly

437
00:17:05,350 --> 00:17:04,400
possible

438
00:17:08,549 --> 00:17:05,360

after

439
00:17:11,110 --> 00:17:08,559
we had ways to actually record

440
00:17:13,429 --> 00:17:11,120
the spectra that we are observing i.e

441
00:17:15,029 --> 00:17:13,439
with the advent of photography so what

442
00:17:17,429 --> 00:17:15,039
you can see here for instance is the

443
00:17:21,990 --> 00:17:19,270
picture not even a picture this is

444
00:17:24,470 --> 00:17:22,000
actually a daguerreotype a prototype of

445
00:17:26,710 --> 00:17:24,480
a photographic plate and this is

446
00:17:29,990 --> 00:17:26,720
actually a spectrum of the sun that was

447
00:17:33,669 --> 00:17:30,000
taken by john draper in 1842

448
00:17:35,190 --> 00:17:33,679
and when we come to the sun and the

449
00:17:37,669 --> 00:17:35,200
first

450
00:17:40,310 --> 00:17:37,679
observation of features well this is a

451
00:17:43,510 --> 00:17:40,320
prime example because spectroscopy is as

452
00:17:45,270 --> 00:17:43,520
i said used to understand the

453
00:17:47,510 --> 00:17:45,280
study the features

454
00:17:49,270 --> 00:17:47,520
in the spectra of different objects and

455
00:17:51,830 --> 00:17:49,280
try to use

456
00:17:54,630 --> 00:17:51,840
this feature to actually infer how the

457
00:17:57,270 --> 00:17:54,640
light is produced from in the k in our

458
00:17:58,830 --> 00:17:57,280
case astrophysical objects such as stars

459
00:18:01,669 --> 00:17:58,840
and gala and

460
00:18:04,390 --> 00:18:01,679
gas and so

461
00:18:07,029 --> 00:18:04,400
this has led a particular to discovery

462
00:18:09,190 --> 00:18:07,039
of different elements early on in the

463
00:18:10,710 --> 00:18:09,200

19th century for extended discovery of

464
00:18:13,430 --> 00:18:10,720
william

465
00:18:16,070 --> 00:18:13,440
in the chromosphere of the sun this was

466
00:18:18,070 --> 00:18:16,080
something that was uh done after a

467
00:18:19,430 --> 00:18:18,080
particular

468
00:18:21,750 --> 00:18:19,440
solar eclipse

469
00:18:23,350 --> 00:18:21,760
by june jose

470
00:18:25,270 --> 00:18:23,360
who noticed that there was a lot of

471
00:18:27,669 --> 00:18:25,280
emission coming from the

472
00:18:29,990 --> 00:18:27,679
corona of the sun and had the idea of

473
00:18:32,070 --> 00:18:30,000
later taking a spectrum and this is was

474
00:18:33,510 --> 00:18:32,080
also done by a normal locker basically

475
00:18:35,430 --> 00:18:33,520
at the same time

476
00:18:37,909 --> 00:18:35,440
and this led to discover

477
00:18:39,669 --> 00:18:37,919
a particular line that was not known at

478
00:18:41,590 --> 00:18:39,679
the time

479
00:18:44,870 --> 00:18:41,600
which turned out to be an entirely new

480
00:18:47,990 --> 00:18:44,880
element that is otherwise very rare

481
00:18:51,190 --> 00:18:48,000
on earth which is ilium

482
00:18:52,870 --> 00:18:51,200
so nowadays we don't use

483
00:18:55,270 --> 00:18:52,880
prism to

484
00:18:57,190 --> 00:18:55,280
create a spectrum we use what is called

485
00:18:58,630 --> 00:18:57,200
a diffracting grating which is a series

486
00:19:00,310 --> 00:18:58,640
of reflecting

487
00:19:01,270 --> 00:19:00,320
surface inclined

488
00:19:03,830 --> 00:19:01,280

and

489
00:19:05,270 --> 00:19:03,840
the light that is that comes on this

490
00:19:08,070 --> 00:19:05,280
diffraction rating because of

491
00:19:09,669 --> 00:19:08,080
diffraction and interfacing at the end

492
00:19:11,350 --> 00:19:09,679
is deflected at different angles

493
00:19:14,150 --> 00:19:11,360
depending on their wavelengths and we

494
00:19:16,710 --> 00:19:14,160
can then collect this with the detector

495
00:19:18,230 --> 00:19:16,720
and actually observe a spectrum

496
00:19:20,789 --> 00:19:18,240
um

497
00:19:22,710 --> 00:19:20,799
why do we use gratings instead of prism

498
00:19:24,630 --> 00:19:22,720
is because we can actually

499
00:19:26,950 --> 00:19:24,640
really be very careful in the

500
00:19:28,950 --> 00:19:26,960
construction of this

501
00:19:30,549 --> 00:19:28,960
of these inclined surfaces and really go

502
00:19:33,510 --> 00:19:30,559
down to very high procedure in

503
00:19:37,430 --> 00:19:33,520
manufacturing so having a great control

504
00:19:39,430 --> 00:19:37,440
on the outcoming spectrum that we get

505
00:19:41,590 --> 00:19:39,440
one particular kind of grating that you

506
00:19:42,870 --> 00:19:41,600
may be familiar yourself are your old

507
00:19:45,029 --> 00:19:42,880
cds

508
00:19:46,789 --> 00:19:45,039
um these are you may have noticed that

509
00:19:48,549 --> 00:19:46,799
when you incline them you actually get a

510
00:19:50,950 --> 00:19:48,559
little rainbow out of these so that's

511
00:19:52,630 --> 00:19:50,960
exactly the process i'm talking about

512
00:19:54,230 --> 00:19:52,640
and in fact

513
00:19:58,390 --> 00:19:54,240

there are ways where you can actually

514
00:20:00,549 --> 00:19:58,400
build your own little uh spectrograph uh

515
00:20:01,830 --> 00:20:00,559
as shown in this picture that you can

516
00:20:03,990 --> 00:20:01,840
use to

517
00:20:07,029 --> 00:20:04,000
point it to different sources such as

518
00:20:07,750 --> 00:20:07,039
the sun itself or maybe

519
00:20:08,870 --> 00:20:07,760
a

520
00:20:11,669 --> 00:20:08,880
light

521
00:20:13,190 --> 00:20:11,679
on incandescent lamps or from a neon

522
00:20:14,710 --> 00:20:13,200
light and then observe the difference of

523
00:20:17,990 --> 00:20:14,720
what you get

524
00:20:21,830 --> 00:20:20,630
sometimes grating is also combined with

525
00:20:24,149 --> 00:20:21,840
the grism

526
00:20:25,990 --> 00:20:24,159
okay uh this is an example of what we

527
00:20:26,789 --> 00:20:26,000
call a grisum then

528
00:20:30,310 --> 00:20:26,799
um

529
00:20:32,070 --> 00:20:30,320
this allows for uh the construction of

530
00:20:34,630 --> 00:20:32,080
more effective and compact instruments

531
00:20:36,789 --> 00:20:34,640
because we don't have to place uh the

532
00:20:39,190 --> 00:20:36,799
camera for imaging outside in a

533
00:20:42,149 --> 00:20:39,200
different direction where we have also

534
00:20:44,149 --> 00:20:42,159
uh on the other end the the light from

535
00:20:47,029 --> 00:20:44,159
the grating coming from a different

536
00:20:49,270 --> 00:20:47,039
direction but we can basically have the

537
00:20:51,350 --> 00:20:49,280
light going straight away through the

538
00:20:53,669 --> 00:20:51,360

instrument put the camera at the end and

539
00:20:56,470 --> 00:20:53,679
then just insert the greeting if we want

540
00:20:58,549 --> 00:20:56,480
to actually have a spectrum or not

541
00:20:59,590 --> 00:20:58,559
anyway this is a bit of technicality i

542
00:21:01,830 --> 00:20:59,600
just wanted to actually give you a

543
00:21:02,950 --> 00:21:01,840
little insight on how these instruments

544
00:21:04,789 --> 00:21:02,960
works

545
00:21:07,430 --> 00:21:04,799
but what do we actually look up in the

546
00:21:08,710 --> 00:21:07,440
sky when we actually take

547
00:21:10,230 --> 00:21:08,720
a spectrum

548
00:21:12,310 --> 00:21:10,240
and what do we learn where does this

549
00:21:13,990 --> 00:21:12,320
light come mostly from well it mostly

550
00:21:16,870 --> 00:21:14,000
comes from stars

551
00:21:17,669 --> 00:21:16,880
and gas in the sky

552
00:21:20,549 --> 00:21:17,679
so

553
00:21:23,669 --> 00:21:20,559
when you see stars these produce

554
00:21:26,310 --> 00:21:23,679
mostly a diffuse continuum spectrum

555
00:21:28,549 --> 00:21:26,320
which is the brighter and the bluer

556
00:21:30,470 --> 00:21:28,559
and the more hotter

557
00:21:31,990 --> 00:21:30,480
is a star

558
00:21:38,230 --> 00:21:32,000
and

559
00:21:40,390 --> 00:21:38,240
absorbed by interstellar gas

560
00:21:42,710 --> 00:21:40,400
and is then re-emitted

561
00:21:45,350 --> 00:21:42,720
at very specific frequency creating what

562
00:21:47,430 --> 00:21:45,360
is actually called an emission spectrum

563
00:21:49,110 --> 00:21:47,440

let me just try to actually put my laser

564
00:21:51,110 --> 00:21:49,120
pointer here so you can see this so

565
00:21:53,270 --> 00:21:51,120
that's what i'm talking about here

566
00:21:55,909 --> 00:21:53,280
so this is the mission spectrum of an

567
00:21:56,950 --> 00:21:55,919
excited cloud of gas as it cools down it

568
00:21:59,190 --> 00:21:56,960
emits

569
00:22:01,190 --> 00:21:59,200
radiation at very specific frequency and

570
00:22:03,190 --> 00:22:01,200
the very excitement

571
00:22:05,270 --> 00:22:03,200
actually takes place in the form of

572
00:22:07,750 --> 00:22:05,280
light from being from the stars being

573
00:22:09,510 --> 00:22:07,760
absorbed at very specific frequency in

574
00:22:11,990 --> 00:22:09,520
turn just like it is a

575
00:22:13,350 --> 00:22:12,000
emitted at very specific frequency it is

576
00:22:15,909 --> 00:22:13,360
also absorbed

577
00:22:19,590 --> 00:22:15,919
at very specific frequency and when this

578
00:22:21,590 --> 00:22:19,600
gas actually is on the surface of a star

579
00:22:22,390 --> 00:22:21,600
so when we actually talking about

580
00:22:24,390 --> 00:22:22,400
the

581
00:22:26,870 --> 00:22:24,400
atmosphere of a star

582
00:22:29,110 --> 00:22:26,880
then it produces a set of absorption

583
00:22:31,029 --> 00:22:29,120
features that indeed we observe in

584
00:22:33,190 --> 00:22:31,039
stellar spectra so a stellar spectrum is

585
00:22:35,350 --> 00:22:33,200
never a continuum it is in fact a

586
00:22:37,669 --> 00:22:35,360
superposition of a stellar continuum and

587
00:22:38,830 --> 00:22:37,679
an absorption spectrum from the gas in

588
00:22:41,029 --> 00:22:38,840

it in its

589
00:22:42,950 --> 00:22:41,039
atmosphere so that's what i'm talking

590
00:22:44,470 --> 00:22:42,960
about and this is very important because

591
00:22:46,789 --> 00:22:44,480
different stars

592
00:22:48,789 --> 00:22:46,799
have different kind of spectra

593
00:22:50,230 --> 00:22:48,799
so there are stars that are very blue

594
00:22:51,190 --> 00:22:50,240
and they're typically

595
00:22:53,669 --> 00:22:51,200
young

596
00:22:55,830 --> 00:22:53,679
and very uh and very bright and then

597
00:22:58,390 --> 00:22:55,840
there are stars that are very red

598
00:23:01,909 --> 00:22:58,400
and there are typically old

599
00:23:03,990 --> 00:23:01,919
however it is the um

600
00:23:05,590 --> 00:23:04,000
the distribution of these absorption

601
00:23:07,990 --> 00:23:05,600
lines that actually tells us something

602
00:23:09,669 --> 00:23:08,000
more about the stars it tells about not

603
00:23:12,390 --> 00:23:09,679
only about the temperature but it also

604
00:23:15,270 --> 00:23:12,400
tells about the surface gravity

605
00:23:17,590 --> 00:23:15,280
and also because these absorption lines

606
00:23:19,430 --> 00:23:17,600
come from specific elements it does also

607
00:23:21,510 --> 00:23:19,440
informs us on the kind of element

608
00:23:24,630 --> 00:23:21,520
abundance on the stars

609
00:23:25,669 --> 00:23:24,640
ultimately this gives a give in gives us

610
00:23:28,390 --> 00:23:25,679
a hint

611
00:23:29,909 --> 00:23:28,400
on the age and evolutionary status of a

612
00:23:30,789 --> 00:23:29,919
star

613
00:23:32,870 --> 00:23:30,799

so

614
00:23:34,870 --> 00:23:32,880
because what you can have

615
00:23:36,789 --> 00:23:34,880
is that you can have you can have red

616
00:23:38,070 --> 00:23:36,799
stars in the sky that are actually

617
00:23:40,710 --> 00:23:38,080
either

618
00:23:42,630 --> 00:23:40,720
normal average small stars and very

619
00:23:44,789 --> 00:23:42,640
bright giant stars and if through the

620
00:23:46,630 --> 00:23:44,799
spectra that we can tell the difference

621
00:23:47,750 --> 00:23:46,640
and this was very important to actually

622
00:23:49,510 --> 00:23:47,760
crack

623
00:23:51,430 --> 00:23:49,520
the riddle

624
00:23:53,190 --> 00:23:51,440
why there are on in the sky different

625
00:23:54,630 --> 00:23:53,200
stars or different colors and different

626
00:23:56,230 --> 00:23:54,640
brightness

627
00:24:00,390 --> 00:23:56,240
so

628
00:24:02,630 --> 00:24:00,400
emission that we can have

629
00:24:05,510 --> 00:24:02,640
as i said our

630
00:24:07,669 --> 00:24:05,520
emission line from from clouds of gas

631
00:24:10,149 --> 00:24:07,679
that is excited a typical example we can

632
00:24:12,549 --> 00:24:10,159
see is the orion nebulae which is

633
00:24:15,110 --> 00:24:12,559
actually gas excited by bright young

634
00:24:18,149 --> 00:24:15,120
stars that have been forming at the very

635
00:24:20,470 --> 00:24:18,159
core of this gas cloud

636
00:24:21,750 --> 00:24:20,480
and in in the case of a stellar spectrum

637
00:24:23,990 --> 00:24:21,760
the feature that we actually are

638
00:24:25,909 --> 00:24:24,000

interested are the mission lines

639
00:24:28,710 --> 00:24:25,919
and the relative intensity of these

640
00:24:30,870 --> 00:24:28,720
mission lines can tell us about again

641
00:24:33,510 --> 00:24:30,880
the element abundance but also the

642
00:24:34,470 --> 00:24:33,520
source of excitation which to put it

643
00:24:37,029 --> 00:24:34,480
simply

644
00:24:39,590 --> 00:24:37,039
in the case of this orion nebula it is

645
00:24:41,590 --> 00:24:39,600
uh you know the young stars but it could

646
00:24:43,029 --> 00:24:41,600
be also in the case of a planetary

647
00:24:46,470 --> 00:24:43,039
nebula

648
00:24:48,470 --> 00:24:46,480
a central much hotter single stars or in

649
00:24:49,990 --> 00:24:48,480
the case of a supernova remnant it could

650
00:24:52,630 --> 00:24:50,000
be the shocks

651
00:24:57,350 --> 00:24:52,640
that the gas actually goes through as it

652
00:25:02,230 --> 00:25:00,710
now how do we go from the single star

653
00:25:03,510 --> 00:25:02,240
stellar spectra that we see in our

654
00:25:04,390 --> 00:25:03,520
galaxy

655
00:25:07,350 --> 00:25:04,400
and

656
00:25:09,590 --> 00:25:07,360
the single gas clouds spectra that we

657
00:25:10,950 --> 00:25:09,600
see also nearby

658
00:25:12,950 --> 00:25:10,960
to understand

659
00:25:15,190 --> 00:25:12,960
the spectra that we obtained from

660
00:25:17,190 --> 00:25:15,200
galaxies now what we need to keep in

661
00:25:19,990 --> 00:25:17,200
mind is that because

662
00:25:21,430 --> 00:25:20,000
galaxies are so far away effectively

663
00:25:23,990 --> 00:25:21,440

what we see

664
00:25:26,549 --> 00:25:24,000
is mostly emission from

665
00:25:27,350 --> 00:25:26,559
very red giant stars

666
00:25:29,990 --> 00:25:27,360
from

667
00:25:32,310 --> 00:25:30,000
very blue bright stars

668
00:25:35,190 --> 00:25:32,320
and from diffuse gas

669
00:25:37,269 --> 00:25:35,200
from uh star forming regions so this is

670
00:25:40,710 --> 00:25:37,279
what gives actually the appearance in in

671
00:25:44,470 --> 00:25:40,720
galaxies of maybe the red

672
00:25:47,029 --> 00:25:44,480
central regions dominated by all giants

673
00:25:47,909 --> 00:25:47,039
the blue spiral arms where you only have

674
00:25:51,190 --> 00:25:47,919
this

675
00:25:53,269 --> 00:25:51,200
star for these very bright young stars

676
00:25:55,350 --> 00:25:53,279
necessarily they have to be here where

677
00:25:58,710 --> 00:25:55,360
you form stars because these red giant

678
00:26:01,990 --> 00:25:58,720
stars red sorry these blue stars

679
00:26:03,510 --> 00:26:02,000
actually don't leave long left life so

680
00:26:05,190 --> 00:26:03,520
if you don't keep forming them they will

681
00:26:06,870 --> 00:26:05,200
soon disappear and then the galaxy will

682
00:26:09,510 --> 00:26:06,880
simply turn red

683
00:26:11,350 --> 00:26:09,520
and then this

684
00:26:14,390 --> 00:26:11,360
with red cloud

685
00:26:15,909 --> 00:26:14,400
of emission lines they become even more

686
00:26:17,990 --> 00:26:15,919
apparent if you actually look at

687
00:26:22,710 --> 00:26:18,000
specific frequencies and take what we

688
00:26:27,669 --> 00:26:25,430

and so overall when you take uh imagine

689
00:26:29,909 --> 00:26:27,679
taking the spectra of a single galaxy

690
00:26:30,870 --> 00:26:29,919
like you know if you could just

691
00:26:32,710 --> 00:26:30,880
take

692
00:26:34,549 --> 00:26:32,720
the spectrum of a galaxy to a single

693
00:26:36,230 --> 00:26:34,559
fiber for instance

694
00:26:38,789 --> 00:26:36,240
then you basically confront it with two

695
00:26:40,390 --> 00:26:38,799
typical kind of galaxy spectra

696
00:26:42,310 --> 00:26:40,400
so on the left

697
00:26:45,510 --> 00:26:42,320
and in blue here what you see is the

698
00:26:47,269 --> 00:26:45,520
spectrum of a galaxy where you have

699
00:26:50,149 --> 00:26:47,279
active star formation

700
00:26:53,110 --> 00:26:50,159
so overall the stellar continuum

701
00:26:55,430 --> 00:26:53,120
looks blue because it is it receives a

702
00:26:56,470 --> 00:26:55,440
lot of contribution from the blue bright

703
00:26:58,549 --> 00:26:56,480
stars

704
00:27:00,470 --> 00:26:58,559
that are continuously forming in the

705
00:27:03,029 --> 00:27:00,480
star forming region and of course you

706
00:27:06,710 --> 00:27:03,039
also have like from the orion nebula

707
00:27:09,669 --> 00:27:06,720
a lot of these emission lines from the

708
00:27:11,990 --> 00:27:09,679
very regions where the stars are forming

709
00:27:14,070 --> 00:27:12,000
conversely in a galaxy where there is no

710
00:27:17,750 --> 00:27:14,080
longer star formation what you have is a

711
00:27:19,269 --> 00:27:17,760
spectrum that is dominated by red stars

712
00:27:20,470 --> 00:27:19,279
and therefore

713
00:27:23,190 --> 00:27:20,480

the step the

714
00:27:25,190 --> 00:27:23,200
total stellar spectrum of a galaxy look

715
00:27:26,710 --> 00:27:25,200
essentially red

716
00:27:28,950 --> 00:27:26,720
and you don't see

717
00:27:31,830 --> 00:27:28,960
any ongoing star formation therefore you

718
00:27:33,830 --> 00:27:31,840
don't see any prominent emission lines

719
00:27:35,430 --> 00:27:33,840
of course life is a bit more complicated

720
00:27:37,029 --> 00:27:35,440
than this sometimes you have emission

721
00:27:39,350 --> 00:27:37,039
lines that come from

722
00:27:40,950 --> 00:27:39,360
gas in the immediate vicinity of an

723
00:27:42,630 --> 00:27:40,960
accreting black hole this will give you

724
00:27:43,669 --> 00:27:42,640
a completely different kind of emission

725
00:27:45,350 --> 00:27:43,679
lines

726
00:27:47,190 --> 00:27:45,360
but i can talk about this maybe in the

727
00:27:49,029 --> 00:27:47,200
questions later

728
00:27:51,190 --> 00:27:49,039
so what can we learn

729
00:27:54,549 --> 00:27:51,200
from this kind of spectra

730
00:27:56,549 --> 00:27:54,559
well we can try to decipher the the

731
00:27:57,590 --> 00:27:56,559
composition of stars that actually

732
00:28:00,149 --> 00:27:57,600
enters

733
00:28:02,710 --> 00:28:00,159
in the final total spectrum or if you

734
00:28:04,710 --> 00:28:02,720
want we can try to find out the mix of

735
00:28:07,510 --> 00:28:04,720
old and young stars

736
00:28:08,870 --> 00:28:07,520
that are ending up in the giving you the

737
00:28:10,630 --> 00:28:08,880
total spectrum

738
00:28:13,110 --> 00:28:10,640

of a galaxy

739
00:28:15,750 --> 00:28:13,120
and we can also infer the total amount

740
00:28:17,669 --> 00:28:15,760
of gas that is being formed excited by

741
00:28:19,909 --> 00:28:17,679
newly formed stars

742
00:28:21,269 --> 00:28:19,919
these two aspects in turn can tell us

743
00:28:23,510 --> 00:28:21,279
something about the star formation

744
00:28:24,710 --> 00:28:23,520
history so if there are a lot of young

745
00:28:30,149 --> 00:28:24,720
stars

746
00:28:32,710 --> 00:28:30,159
then it means that we are actually

747
00:28:34,549 --> 00:28:32,720
forming stars whereas in galaxies like

748
00:28:36,870 --> 00:28:34,559
this you will find that the star

749
00:28:39,110 --> 00:28:36,880
formation is the way it badly

750
00:28:41,430 --> 00:28:39,120
was quenched long time ago and there

751
00:28:44,870 --> 00:28:41,440
hasn't been any new star or even even

752
00:28:46,789 --> 00:28:44,880
intermediate star for some time

753
00:28:48,789 --> 00:28:46,799
and then the mission lines that tell you

754
00:28:50,789 --> 00:28:48,799
actually how many stars are presently

755
00:28:52,950 --> 00:28:50,799
forming so the present rate of star

756
00:28:55,190 --> 00:28:52,960
formation and of course this kind of

757
00:29:01,750 --> 00:28:55,200
exercise can be done both for nearby

758
00:29:05,269 --> 00:29:03,430
another thing that we can do which i'm

759
00:29:08,070 --> 00:29:05,279
sure you're familiar with

760
00:29:10,230 --> 00:29:08,080
with spectra is to use the doppler

761
00:29:13,990 --> 00:29:10,240
effect

762
00:29:16,070 --> 00:29:14,000
to essentially measure the velocity of

763
00:29:17,750 --> 00:29:16,080

the stars and of the gas

764
00:29:20,070 --> 00:29:17,760
what we do is that for instance if we

765
00:29:21,909 --> 00:29:20,080
have a galaxy that is rotating

766
00:29:24,230 --> 00:29:21,919
what we can observe

767
00:29:26,310 --> 00:29:24,240
is that the gas and the stars

768
00:29:28,389 --> 00:29:26,320
on this side of the galaxy imagine that

769
00:29:30,630 --> 00:29:28,399
imagine that the galaxy is you know

770
00:29:33,269 --> 00:29:30,640
rotating this way as you see then the

771
00:29:35,669 --> 00:29:33,279
stars and the gas in this side of the

772
00:29:38,070 --> 00:29:35,679
galaxy will be receding from us

773
00:29:40,310 --> 00:29:38,080
therefore the initial line from the gas

774
00:29:41,990 --> 00:29:40,320
and the absorption lines from the stars

775
00:29:44,389 --> 00:29:42,000
will be redshifted

776
00:29:45,430 --> 00:29:44,399
and the amount of redshift that i will

777
00:29:48,549 --> 00:29:45,440
measure

778
00:29:49,990 --> 00:29:48,559
can be translated directly into a

779
00:29:52,070 --> 00:29:50,000
velocity

780
00:29:55,350 --> 00:29:52,080
and likewise

781
00:29:56,950 --> 00:29:55,360
on the blue side on the

782
00:29:59,830 --> 00:29:56,960
approaching side i will actually be

783
00:30:02,070 --> 00:29:59,840
measuring a blue shift

784
00:30:05,269 --> 00:30:02,080
and therefore a negative velocity

785
00:30:08,230 --> 00:30:05,279
towards me this is of course uh once we

786
00:30:08,870 --> 00:30:08,240
take out the overall redshift

787
00:30:11,430 --> 00:30:08,880
and

788
00:30:13,510 --> 00:30:11,440

of the of the galaxy because this is due

789
00:30:15,590 --> 00:30:13,520
to the expansion of the universe

790
00:30:17,590 --> 00:30:15,600
so the galaxy is actually moving overall

791
00:30:20,070 --> 00:30:17,600
away from us most of the times except

792
00:30:22,389 --> 00:30:20,080
for the mostly most close galaxies that

793
00:30:26,230 --> 00:30:22,399
actually like andromeda is falling on to

794
00:30:29,269 --> 00:30:27,269
um

795
00:30:31,190 --> 00:30:29,279
so let's now go back to spectroscopy and

796
00:30:33,830 --> 00:30:31,200
let's talk let's try to understand how

797
00:30:35,510 --> 00:30:33,840
this is done in telescopes

798
00:30:37,830 --> 00:30:35,520
the simplest thing that you can do is

799
00:30:40,789 --> 00:30:37,840
that you can simply take your algorithm

800
00:30:42,630 --> 00:30:40,799
or your grating and put it in you know

801
00:30:45,110 --> 00:30:42,640
across the optical path

802
00:30:48,710 --> 00:30:45,120
and simply transform what you see

803
00:30:51,110 --> 00:30:48,720
a an image into a set of spectra

804
00:30:53,510 --> 00:30:51,120
hst has such kind of technique which is

805
00:30:56,310 --> 00:30:53,520
called liquid spectroscopy and in this

806
00:30:59,509 --> 00:30:56,320
case what you can see is you know images

807
00:31:00,630 --> 00:30:59,519
of of distant galaxies

808
00:31:02,630 --> 00:31:00,640
that

809
00:31:04,950 --> 00:31:02,640
for which you immediately get some short

810
00:31:06,630 --> 00:31:04,960
spectra here

811
00:31:08,070 --> 00:31:06,640
this is very useful and very efficient

812
00:31:10,389 --> 00:31:08,080
because you get lots of spectra at the

813
00:31:11,990 --> 00:31:10,399

same time

814
00:31:14,149 --> 00:31:12,000
and it's very good when you have

815
00:31:17,509 --> 00:31:14,159
discrete sources and distinct sources

816
00:31:22,470 --> 00:31:20,310
but for a galaxy that won't work

817
00:31:23,990 --> 00:31:22,480
because what you have is that you have

818
00:31:26,470 --> 00:31:24,000
continuous

819
00:31:28,549 --> 00:31:26,480
sources one next to each other

820
00:31:30,789 --> 00:31:28,559
okay and even here you can see that some

821
00:31:32,470 --> 00:31:30,799
these three galaxies for instance you it

822
00:31:34,310 --> 00:31:32,480
is are to actually

823
00:31:35,590 --> 00:31:34,320
their spectra actually superimposed to

824
00:31:38,789 --> 00:31:35,600
each other

825
00:31:41,750 --> 00:31:38,799
so imagine this for a diffuse source of

826
00:31:44,950 --> 00:31:41,760
light such as you know a galaxy where

827
00:31:46,630 --> 00:31:44,960
the light comes from every place

828
00:31:48,149 --> 00:31:46,640
so in this case what you can do is that

829
00:31:50,470 --> 00:31:48,159
you have to make a hard choice and

830
00:31:53,190 --> 00:31:50,480
decide that you want to only look

831
00:31:55,590 --> 00:31:53,200
at an at one part of the galaxy like in

832
00:31:57,110 --> 00:31:55,600
a long slit in this case in only one

833
00:31:59,190 --> 00:31:57,120
direction

834
00:32:01,190 --> 00:31:59,200
and essentially just take the spectrum

835
00:32:02,870 --> 00:32:01,200
of this region of this region of this

836
00:32:05,110 --> 00:32:02,880
region of this region

837
00:32:07,110 --> 00:32:05,120
and take this region and disperse them

838
00:32:09,110 --> 00:32:07,120

along the wave and direction when you

839
00:32:11,750 --> 00:32:09,120
put them through the

840
00:32:13,190 --> 00:32:11,760
through your spectrograph so what you

841
00:32:15,029 --> 00:32:13,200
see in here is

842
00:32:17,669 --> 00:32:15,039
a typical

843
00:32:20,470 --> 00:32:17,679
long sleeve spectrum of a galaxy where

844
00:32:22,630 --> 00:32:20,480
you see a very bright continuum coming

845
00:32:24,710 --> 00:32:22,640
from the center center region of a

846
00:32:26,870 --> 00:32:24,720
galaxy which is very bright

847
00:32:28,870 --> 00:32:26,880
and then you see also some absorption

848
00:32:33,669 --> 00:32:28,880
lines here and you can see also some

849
00:32:37,269 --> 00:32:35,590
now this is needed as i said to avoid

850
00:32:38,630 --> 00:32:37,279
overlapping but it's not particularly

851
00:32:40,789 --> 00:32:38,640
efficient

852
00:32:43,350 --> 00:32:40,799
if i really want to cover understand the

853
00:32:45,029 --> 00:32:43,360
galaxy property well i also need at

854
00:32:48,389 --> 00:32:45,039
least to put something along the minor

855
00:32:50,789 --> 00:32:48,399
axis or maybe at an intermediate angle

856
00:32:52,710 --> 00:32:50,799
and every time i do this i have to

857
00:32:54,389 --> 00:32:52,720
expose again at my telescope and it

858
00:32:56,710 --> 00:32:54,399
takes a lot of time to essentially

859
00:32:57,990 --> 00:32:56,720
through this method to cover the entire

860
00:33:00,950 --> 00:32:58,000
galaxy

861
00:33:03,509 --> 00:33:00,960
true galaxies are also accessible they

862
00:33:05,350 --> 00:33:03,519
have a symmetry so in the end of the day

863
00:33:07,269 --> 00:33:05,360

i could say that you know if i have a

864
00:33:09,669 --> 00:33:07,279
disk what i observe here should also be

865
00:33:13,350 --> 00:33:09,679
observed here and here and here and here

866
00:33:15,110 --> 00:33:13,360
but not all galaxies are accessible

867
00:33:16,870 --> 00:33:15,120
and also there is another important

868
00:33:18,310 --> 00:33:16,880
thing to keep in mind aspect to keep in

869
00:33:20,389 --> 00:33:18,320
mind is that

870
00:33:21,509 --> 00:33:20,399
as i move into the fainter region of a

871
00:33:23,750 --> 00:33:21,519
galaxy

872
00:33:26,310 --> 00:33:23,760
i collect less and less light ideally

873
00:33:28,470 --> 00:33:26,320
what i would like is to be able to have

874
00:33:30,230 --> 00:33:28,480
a bigger slate here and

875
00:33:32,950 --> 00:33:30,240
add everything together and this is

876
00:33:34,549 --> 00:33:32,960
precisely what is actually possible when

877
00:33:35,830 --> 00:33:34,559
instead of

878
00:33:38,070 --> 00:33:35,840
going

879
00:33:39,590 --> 00:33:38,080
only in one possible direction you can

880
00:33:41,909 --> 00:33:39,600
actually take

881
00:33:44,310 --> 00:33:41,919
a spectrum everywhere in your field of

882
00:33:49,029 --> 00:33:45,830
so this is where integral field

883
00:33:51,350 --> 00:33:49,039
spectroscopy comes comes in play

884
00:33:53,990 --> 00:33:51,360
there are various ways to do this um

885
00:33:56,310 --> 00:33:54,000
early concept actually used

886
00:33:57,990 --> 00:33:56,320
um what is called landslides so the idea

887
00:33:59,990 --> 00:33:58,000
here is that you have to have the focal

888
00:34:01,909 --> 00:34:00,000

plane at the focal plane you have to

889
00:34:03,830 --> 00:34:01,919
split your galaxy image you have the

890
00:34:05,909 --> 00:34:03,840
light coming from the galaxy

891
00:34:07,909 --> 00:34:05,919
that is focused on the focal plane and

892
00:34:09,990 --> 00:34:07,919
at that point you actually have to find

893
00:34:12,230 --> 00:34:10,000
ways to split the light from the of the

894
00:34:14,869 --> 00:34:12,240
galaxy so you can have little landslides

895
00:34:17,030 --> 00:34:14,879
that focus these regions in little

896
00:34:20,470 --> 00:34:17,040
regions here just before you go to your

897
00:34:22,629 --> 00:34:20,480
spectrograph and then you obtain very

898
00:34:24,230 --> 00:34:22,639
you know various little spectra here

899
00:34:26,230 --> 00:34:24,240
that's one concept

900
00:34:27,510 --> 00:34:26,240
another concept is that you attach a

901
00:34:31,510 --> 00:34:27,520
fiber

902
00:34:32,869 --> 00:34:31,520
of your focal plane and then you carry

903
00:34:34,950 --> 00:34:32,879
the fiber

904
00:34:37,030 --> 00:34:34,960
uh and you align them along the

905
00:34:38,950 --> 00:34:37,040
direction of where you typically have a

906
00:34:41,349 --> 00:34:38,960
slit and then you pass this to the

907
00:34:43,589 --> 00:34:41,359
spectrograph and again you have a series

908
00:34:45,430 --> 00:34:43,599
of long slick spectra

909
00:34:48,710 --> 00:34:45,440
or you can have an image slicer where

910
00:34:50,149 --> 00:34:48,720
you take this image and you send it here

911
00:34:51,990 --> 00:34:50,159
this image and you send it to you and

912
00:34:53,270 --> 00:34:52,000
you're here and then again it's long a

913
00:34:55,430 --> 00:34:53,280

longest lead

914
00:34:58,550 --> 00:34:55,440
either way what you at the end you end

915
00:35:00,630 --> 00:34:58,560
up is with a spectrum

916
00:35:03,030 --> 00:35:00,640
everywhere in your field of view of

917
00:35:05,430 --> 00:35:03,040
course it's not everywhere and there is

918
00:35:06,710 --> 00:35:05,440
a finite resolution that comes out of

919
00:35:08,310 --> 00:35:06,720
this process

920
00:35:10,870 --> 00:35:08,320
and you end up with what is actually

921
00:35:13,349 --> 00:35:10,880
called a data cube

922
00:35:15,270 --> 00:35:13,359
the data cube actually you can see it in

923
00:35:17,829 --> 00:35:15,280
these two different ways

924
00:35:19,670 --> 00:35:17,839
you can see it as a spectrum at every

925
00:35:21,109 --> 00:35:19,680
place in the galaxy

926
00:35:23,829 --> 00:35:21,119
so for instance this is actually a

927
00:35:26,069 --> 00:35:23,839
spectrum that is in this place then the

928
00:35:27,190 --> 00:35:26,079
spectrum from the center and spectrum

929
00:35:29,430 --> 00:35:27,200
from here

930
00:35:32,470 --> 00:35:29,440
so you can extract the spectrum at every

931
00:35:35,030 --> 00:35:32,480
location of the galaxy which of course

932
00:35:36,870 --> 00:35:35,040
or a nebula i'm just talking about any

933
00:35:38,550 --> 00:35:36,880
diffuse object here

934
00:35:41,030 --> 00:35:38,560
which is very useful because you can

935
00:35:43,430 --> 00:35:41,040
learn about all these kind of properties

936
00:35:46,710 --> 00:35:43,440
about the stellar content or the amount

937
00:35:49,430 --> 00:35:46,720
of gas that has been excited by stars

938
00:35:51,910 --> 00:35:49,440

everywhere in the galaxy

939
00:35:53,670 --> 00:35:51,920
or you can look at this as a series of

940
00:35:56,550 --> 00:35:53,680
monochromatic

941
00:35:58,470 --> 00:35:56,560
images so at every place

942
00:36:00,870 --> 00:35:58,480
as you travel through the cube

943
00:36:02,870 --> 00:36:00,880
you can actually see an image the image

944
00:36:04,870 --> 00:36:02,880
will be slightly different at every

945
00:36:06,550 --> 00:36:04,880
wavelength depending on

946
00:36:07,589 --> 00:36:06,560
what is actually happening to the

947
00:36:09,589 --> 00:36:07,599
spectra

948
00:36:12,150 --> 00:36:09,599
so at some point you may actually have

949
00:36:13,990 --> 00:36:12,160
very strong emission lines coming up and

950
00:36:16,870 --> 00:36:14,000
you will be able to see this in the

951
00:36:19,349 --> 00:36:18,069
so

952
00:36:22,069 --> 00:36:19,359
when it comes to

953
00:36:24,870 --> 00:36:22,079
multi-full field spectrum

954
00:36:27,109 --> 00:36:24,880
spectrograph

955
00:36:29,349 --> 00:36:27,119
the most powerful

956
00:36:32,710 --> 00:36:29,359
ifu that we have at the moment

957
00:36:35,510 --> 00:36:32,720
is the so-called muse spectrograph this

958
00:36:36,550 --> 00:36:35,520
is based on the very large telescope at

959
00:36:42,150 --> 00:36:36,560
the

960
00:36:45,270 --> 00:36:42,160
and what actually seen in this animation

961
00:36:46,550 --> 00:36:45,280
is the orion nebula that i saw show you

962
00:36:47,990 --> 00:36:46,560
before

963
00:36:52,230 --> 00:36:48,000

so let me just

964
00:36:56,470 --> 00:36:54,230
because i actually wanted to start this

965
00:36:57,040 --> 00:36:56,480
other movie

966
00:36:58,550 --> 00:36:57,050
and i can

967
00:37:00,550 --> 00:36:58,560
[Music]

968
00:37:03,190 --> 00:37:00,560
talk about them at the same time so what

969
00:37:04,950 --> 00:37:03,200
you see is that is the is a particular

970
00:37:10,870 --> 00:37:04,960
galaxy

971
00:37:13,030 --> 00:37:10,880
where there is a main body

972
00:37:14,390 --> 00:37:13,040
there is basically a disc and then there

973
00:37:15,750 --> 00:37:14,400
is a polar ring

974
00:37:18,069 --> 00:37:15,760
of

975
00:37:19,589 --> 00:37:18,079
gas that has been acquired gas and stars

976
00:37:20,829 --> 00:37:19,599
that have been acquired

977
00:37:24,390 --> 00:37:20,839
in a second

978
00:37:27,030 --> 00:37:24,400
time and so as we move through the cube

979
00:37:28,390 --> 00:37:27,040
you can see different images

980
00:37:30,150 --> 00:37:28,400
and now you will see for instance the

981
00:37:32,470 --> 00:37:30,160
image that comes in a very particular

982
00:37:34,790 --> 00:37:32,480
moment when we pass through

983
00:37:37,430 --> 00:37:34,800
a particular place where you have a very

984
00:37:38,950 --> 00:37:37,440
strong emission line from hydrogen and

985
00:37:40,630 --> 00:37:38,960
then you will see

986
00:37:42,790 --> 00:37:40,640
first emission from one side to the

987
00:37:44,150 --> 00:37:42,800
galaxy and then the mission

988
00:37:45,910 --> 00:37:44,160

from the other side of the galaxy

989
00:37:47,430 --> 00:37:45,920
because that's where the lines are

990
00:37:50,870 --> 00:37:47,440
according to the redshift because of

991
00:37:53,589 --> 00:37:50,880
their velocity inside the galaxy

992
00:37:55,589 --> 00:37:53,599
and here was the orion nebula and on the

993
00:37:58,310 --> 00:37:55,599
other end this movie was actually

994
00:38:00,630 --> 00:37:58,320
showing you the idea of having

995
00:38:02,790 --> 00:38:00,640
monochromatic images

996
00:38:05,109 --> 00:38:02,800
and again here it's showing you images

997
00:38:07,030 --> 00:38:05,119
in the blue and the green in the red

998
00:38:08,630 --> 00:38:07,040
and also at this very particular special

999
00:38:14,390 --> 00:38:08,640
wavelengths i was talking about where

1000
00:38:18,950 --> 00:38:16,550
so

1001
00:38:22,950 --> 00:38:18,960
i want mostly to talk about integral

1002
00:38:25,270 --> 00:38:22,960
field spectroscopy and apply to galaxies

1003
00:38:26,150 --> 00:38:25,280
uh i have to make a choice here

1004
00:38:27,910 --> 00:38:26,160
um

1005
00:38:30,230 --> 00:38:27,920
and so i need to give you a very short

1006
00:38:32,310 --> 00:38:30,240
introduction they are very nice very

1007
00:38:34,950 --> 00:38:32,320
short introduction that you can find on

1008
00:38:37,510 --> 00:38:34,960
on the web and booklets

1009
00:38:39,190 --> 00:38:37,520
and one these are some of my favorites

1010
00:38:40,069 --> 00:38:39,200
um

1011
00:38:42,470 --> 00:38:40,079
and

1012
00:38:44,550 --> 00:38:42,480
so what about galaxies what is the

1013
00:38:46,310 --> 00:38:44,560

riddle of galaxies what do we see about

1014
00:38:47,750 --> 00:38:46,320
galaxy why are these so important well

1015
00:38:49,510 --> 00:38:47,760
they are the building block of the

1016
00:38:51,109 --> 00:38:49,520
universe as we know it where most of the

1017
00:38:53,910 --> 00:38:51,119
barriers are

1018
00:38:56,630 --> 00:38:53,920
and they come in different shapes and

1019
00:38:59,670 --> 00:38:56,640
colors they are not simple objects

1020
00:39:02,710 --> 00:38:59,680
some are disky some are rounder

1021
00:39:04,950 --> 00:39:02,720
some are red some are bluer

1022
00:39:06,710 --> 00:39:04,960
they also come in wide range of mass and

1023
00:39:08,790 --> 00:39:06,720
sizes

1024
00:39:12,630 --> 00:39:08,800
so first this is an image of the fornax

1025
00:39:14,870 --> 00:39:12,640
cluster which is a big galaxy cluster

1026
00:39:15,990 --> 00:39:14,880
in the south in the constellation of

1027
00:39:17,270 --> 00:39:16,000
phonaks

1028
00:39:19,430 --> 00:39:17,280
and

1029
00:39:21,829 --> 00:39:19,440
you may not see all the galaxies in this

1030
00:39:22,950 --> 00:39:21,839
image but these are actually all little

1031
00:39:24,790 --> 00:39:22,960
galaxies

1032
00:39:27,349 --> 00:39:24,800
so there are

1033
00:39:29,190 --> 00:39:27,359
many galaxies that are very small and a

1034
00:39:31,510 --> 00:39:29,200
few galaxies that are very big so this

1035
00:39:32,470 --> 00:39:31,520
is what we call the mass

1036
00:39:34,950 --> 00:39:32,480
function

1037
00:39:36,950 --> 00:39:34,960
of galaxies so different colors

1038
00:39:38,710 --> 00:39:36,960

different shapes wide range of mass and

1039
00:39:39,670 --> 00:39:38,720
sizes

1040
00:39:42,710 --> 00:39:39,680
and

1041
00:39:44,310 --> 00:39:42,720
finally how do they go to end to this

1042
00:39:45,750 --> 00:39:44,320
present size and shape and color

1043
00:39:47,510 --> 00:39:45,760
distribution what is what are the

1044
00:39:48,470 --> 00:39:47,520
processes

1045
00:39:50,550 --> 00:39:48,480
so

1046
00:39:54,390 --> 00:39:50,560
essentially we can think in a nutshell

1047
00:39:57,030 --> 00:39:54,400
of galaxies as growing through two main

1048
00:39:58,069 --> 00:39:57,040
processes one is star formation where

1049
00:39:59,750 --> 00:39:58,079
you

1050
00:40:02,870 --> 00:39:59,760
accrete over time

1051
00:40:05,109 --> 00:40:02,880
gas from the intergalactic medium

1052
00:40:06,550 --> 00:40:05,119
this gas cools down

1053
00:40:09,510 --> 00:40:06,560
in the plane

1054
00:40:12,870 --> 00:40:09,520
equatorial plane of a galaxy

1055
00:40:15,190 --> 00:40:12,880
and form stars in the process

1056
00:40:17,750 --> 00:40:15,200
when it forms stars this will lead to

1057
00:40:20,630 --> 00:40:17,760
the formation of a stellar disk

1058
00:40:22,630 --> 00:40:20,640
and it will have bluer colors because as

1059
00:40:25,190 --> 00:40:22,640
i said before this would be the light

1060
00:40:26,950 --> 00:40:25,200
would be dominated by the blue stars

1061
00:40:29,750 --> 00:40:26,960
which are the young ones and they are

1062
00:40:35,670 --> 00:40:33,109
um another way to actually grow galaxies

1063
00:40:37,910 --> 00:40:35,680

is to simply merge them together

1064
00:40:39,990 --> 00:40:37,920
frank just showed a lot of pictures of

1065
00:40:42,069 --> 00:40:40,000
merging galaxies before these are

1066
00:40:44,390 --> 00:40:42,079
beautiful features and they actually

1067
00:40:46,870 --> 00:40:44,400
show that galaxy can merge together in

1068
00:40:48,870 --> 00:40:46,880
the nearby universe actually these

1069
00:40:50,950 --> 00:40:48,880
processes are quite rare

1070
00:40:54,230 --> 00:40:50,960
they are not that frequent but when they

1071
00:40:55,910 --> 00:40:54,240
happen a galaxy can simple can you know

1072
00:40:57,829 --> 00:40:55,920
in the end just double its size in one

1073
00:41:00,230 --> 00:40:57,839
go if we get counters or galaxies of

1074
00:41:02,550 --> 00:41:00,240
similar size as it would be the case in

1075
00:41:04,309 --> 00:41:02,560
the future between our own galaxies and

1076
00:41:05,589 --> 00:41:04,319
the andromeda galaxy that you see on the

1077
00:41:07,349 --> 00:41:05,599
left

1078
00:41:08,630 --> 00:41:07,359
when you actually have these big mergers

1079
00:41:11,190 --> 00:41:08,640
you also have

1080
00:41:13,430 --> 00:41:11,200
a lot of star formation that is trigger

1081
00:41:15,589 --> 00:41:13,440
as the gas is funneled towards the

1082
00:41:17,990 --> 00:41:15,599
central regions

1083
00:41:20,870 --> 00:41:18,000
and accumulates there

1084
00:41:23,750 --> 00:41:20,880
and it gets compressed and therefore

1085
00:41:25,990 --> 00:41:23,760
cooling is favored is uh

1086
00:41:27,109 --> 00:41:26,000
happens more easily

1087
00:41:28,710 --> 00:41:27,119
and

1088
00:41:30,309 --> 00:41:28,720

what actually happens in the process is

1089
00:41:31,430 --> 00:41:30,319
that you may start with two disc

1090
00:41:34,390 --> 00:41:31,440
galaxies

1091
00:41:36,470 --> 00:41:34,400
but as the stars gets reassembled and

1092
00:41:38,870 --> 00:41:36,480
fly by each other in the end you may end

1093
00:41:44,230 --> 00:41:38,880
up with around the galaxies like an

1094
00:41:47,670 --> 00:41:45,910
some galaxies however have stopped

1095
00:41:49,910 --> 00:41:47,680
forming stars long ago

1096
00:41:52,470 --> 00:41:49,920
and this is the other end of the process

1097
00:41:54,390 --> 00:41:52,480
you can grow stars you can grow galaxies

1098
00:41:57,510 --> 00:41:54,400
by merging together

1099
00:41:59,589 --> 00:41:57,520
but then sometimes stars stop forming

1100
00:42:01,510 --> 00:41:59,599
and there must be some star forming

1101
00:42:03,109 --> 00:42:01,520
quenching mechanism and we know of some

1102
00:42:05,190 --> 00:42:03,119
of them

1103
00:42:06,790 --> 00:42:05,200
so what we see on the left is star

1104
00:42:08,870 --> 00:42:06,800
formation that is

1105
00:42:10,790 --> 00:42:08,880
quenched by

1106
00:42:13,190 --> 00:42:10,800
star formation itself in a sense what

1107
00:42:15,829 --> 00:42:13,200
you have is that as stars form

1108
00:42:17,349 --> 00:42:15,839
furiously in the center of a galaxy

1109
00:42:19,829 --> 00:42:17,359
then through their radiation and

1110
00:42:20,790 --> 00:42:19,839
supernova explosion they may actually

1111
00:42:23,750 --> 00:42:20,800
funnel

1112
00:42:26,950 --> 00:42:23,760
away the gas from the central regions

1113
00:42:29,190 --> 00:42:26,960

and perpendicularly out of the galaxy

1114
00:42:30,630 --> 00:42:29,200
sometimes this gas goes in the very

1115
00:42:32,630 --> 00:42:30,640
center where

1116
00:42:35,030 --> 00:42:32,640
we now know there are many supermassive

1117
00:42:36,630 --> 00:42:35,040
black holes when these black holes start

1118
00:42:38,950 --> 00:42:36,640
to accrete gas

1119
00:42:41,190 --> 00:42:38,960
they actually become active

1120
00:42:43,030 --> 00:42:41,200
in the sense that their outer region

1121
00:42:44,630 --> 00:42:43,040
their their in you know outside the

1122
00:42:47,109 --> 00:42:44,640
black hole what you have is that you

1123
00:42:48,069 --> 00:42:47,119
form an accretion disk that becomes very

1124
00:42:50,309 --> 00:42:48,079
hot

1125
00:42:53,430 --> 00:42:50,319
radiates a lot of light and also you

1126
00:42:54,870 --> 00:42:53,440
form a jet of high energy particles both

1127
00:42:58,309 --> 00:42:54,880
this kind of

1128
00:43:00,550 --> 00:42:58,319
very energetic processes can drive gas

1129
00:43:03,109 --> 00:43:00,560
out of galaxy or

1130
00:43:06,069 --> 00:43:03,119
they can actually heat up the gas around

1131
00:43:08,550 --> 00:43:06,079
the galaxies and either way you don't

1132
00:43:11,589 --> 00:43:08,560
have any more gas or you have gas that

1133
00:43:13,670 --> 00:43:11,599
is heated up and not cooling down to

1134
00:43:15,670 --> 00:43:13,680
form new stars

1135
00:43:18,870 --> 00:43:15,680
and then you also have environmental

1136
00:43:20,710 --> 00:43:18,880
processes where galaxies join galaxy

1137
00:43:22,950 --> 00:43:20,720
group or clusters

1138
00:43:24,309 --> 00:43:22,960

and get stripped of their gas in the

1139
00:43:26,069 --> 00:43:24,319
process

1140
00:43:28,390 --> 00:43:26,079
or through interaction with other

1141
00:43:31,109 --> 00:43:28,400
galaxies also see

1142
00:43:31,650 --> 00:43:31,119
their gas material being lost

1143
00:43:33,349 --> 00:43:31,660
um

1144
00:43:35,030 --> 00:43:33,359
[Music]

1145
00:43:36,710 --> 00:43:35,040
and of course this is actually a very

1146
00:43:38,069 --> 00:43:36,720
important process

1147
00:43:40,790 --> 00:43:38,079
because

1148
00:43:42,870 --> 00:43:40,800
we know that galaxies uh

1149
00:43:45,270 --> 00:43:42,880
you know live also in different kind of

1150
00:43:47,750 --> 00:43:45,280
environments there are galaxies in group

1151
00:43:49,670 --> 00:43:47,760
in clusters and also in the field

1152
00:43:51,510 --> 00:43:49,680
and whether you are in a group in a

1153
00:43:53,829 --> 00:43:51,520
cluster in the field also affects your

1154
00:43:55,670 --> 00:43:53,839
chances of meeting other galaxies or to

1155
00:43:58,550 --> 00:43:55,680
effectively

1156
00:44:02,870 --> 00:43:58,560
merge with other galaxies and in turn

1157
00:44:05,349 --> 00:44:02,880
this you know limits your chances of

1158
00:44:07,349 --> 00:44:05,359
growing by mergers

1159
00:44:08,870 --> 00:44:07,359
so in a nutshell these are many of the

1160
00:44:11,030 --> 00:44:08,880
processes that we know

1161
00:44:12,150 --> 00:44:11,040
are regulating

1162
00:44:13,589 --> 00:44:12,160
the growth

1163
00:44:15,750 --> 00:44:13,599

of stars

1164
00:44:17,270 --> 00:44:15,760
and galaxies

1165
00:44:18,870 --> 00:44:17,280
but we need to get this picture right

1166
00:44:21,589 --> 00:44:18,880
also across time

1167
00:44:22,950 --> 00:44:21,599
and so what we have here is a graph that

1168
00:44:25,670 --> 00:44:22,960
shows you

1169
00:44:28,470 --> 00:44:25,680
how the star formation

1170
00:44:30,870 --> 00:44:28,480
this is shown by this crosses here

1171
00:44:33,109 --> 00:44:30,880
or the black hole accretion

1172
00:44:34,790 --> 00:44:33,119
and basically how fast black holes are

1173
00:44:36,470 --> 00:44:34,800
were actually growing

1174
00:44:39,349 --> 00:44:36,480
over time

1175
00:44:42,550 --> 00:44:39,359
and so in the nearby universe we can see

1176
00:44:44,150 --> 00:44:42,560
say this present rate of star formation

1177
00:44:46,390 --> 00:44:44,160
but when we go back

1178
00:44:48,550 --> 00:44:46,400
at redshift one or two so redshift one

1179
00:44:50,710 --> 00:44:48,560
is roughly half of the age of the

1180
00:44:52,630 --> 00:44:50,720
present universe where hf2 is something

1181
00:44:53,829 --> 00:44:52,640
like three years after

1182
00:44:56,069 --> 00:44:53,839
big bang

1183
00:44:58,390 --> 00:44:56,079
this is the e-book where galaxies were

1184
00:44:59,910 --> 00:44:58,400
forming star a lot more intensely than

1185
00:45:02,069 --> 00:44:59,920
now

1186
00:45:03,109 --> 00:45:02,079
and likewise also their black holes were

1187
00:45:05,270 --> 00:45:03,119
forming

1188
00:45:07,190 --> 00:45:05,280

uh we're growing actually and accreting

1189
00:45:08,309 --> 00:45:07,200
a lot of more of this gas

1190
00:45:09,829 --> 00:45:08,319
and growing

1191
00:45:11,750 --> 00:45:09,839
accordingly

1192
00:45:12,630 --> 00:45:11,760
so we also need to get this picture

1193
00:45:14,950 --> 00:45:12,640
right

1194
00:45:18,069 --> 00:45:14,960
there are two processes in which we can

1195
00:45:21,030 --> 00:45:18,079
understand galaxy formation

1196
00:45:22,470 --> 00:45:21,040
one is to look at galaxy nearby in

1197
00:45:24,390 --> 00:45:22,480
greater detail

1198
00:45:26,870 --> 00:45:24,400
and the best example is actually to look

1199
00:45:28,790 --> 00:45:26,880
at you know the stars and gas in our

1200
00:45:30,950 --> 00:45:28,800
milky way although unfortunately we are

1201
00:45:32,630 --> 00:45:30,960
limited in where we actually can study

1202
00:45:34,550 --> 00:45:32,640
these objects

1203
00:45:36,470 --> 00:45:34,560
directly in our neighborhood or

1204
00:45:37,910 --> 00:45:36,480
basically mostly on our alpha of the

1205
00:45:41,349 --> 00:45:37,920
galaxy

1206
00:45:44,470 --> 00:45:41,359
or we can look back in time and

1207
00:45:46,870 --> 00:45:44,480
look closer at galaxies when they you

1208
00:45:49,109 --> 00:45:46,880
know look far back in time

1209
00:45:50,870 --> 00:45:49,119
but with less detail

1210
00:45:53,750 --> 00:45:50,880
so integral field spectroscopy can

1211
00:45:57,589 --> 00:45:53,760
actually help in both approaches as also

1212
00:46:02,790 --> 00:46:01,109
so let me just give you a little uh

1213
00:46:04,470 --> 00:46:02,800

two example of our integral view

1214
00:46:06,470 --> 00:46:04,480
spectroscopy can tackle on these

1215
00:46:08,870 --> 00:46:06,480
processes that i mentioned before in

1216
00:46:11,349 --> 00:46:08,880
terms of growing stars

1217
00:46:13,510 --> 00:46:11,359
um this is not necessarily linked to

1218
00:46:16,550 --> 00:46:13,520
the role with humble i just want to give

1219
00:46:18,309 --> 00:46:16,560
you a little into use this two example

1220
00:46:20,630 --> 00:46:18,319
to actually shows you actually how

1221
00:46:22,870 --> 00:46:20,640
integral field spectroscopy works

1222
00:46:24,790 --> 00:46:22,880
so what you are on the left here is a

1223
00:46:26,790 --> 00:46:24,800
nibble space telescope images of a

1224
00:46:28,710 --> 00:46:26,800
beautiful galaxy which is called ngc

1225
00:46:31,109 --> 00:46:28,720
7742

1226
00:46:32,069 --> 00:46:31,119
which has a bright

1227
00:46:35,349 --> 00:46:32,079
core

1228
00:46:37,670 --> 00:46:35,359
of what we call a bulge of yellow stars

1229
00:46:39,670 --> 00:46:37,680
and then it's surrounded by a ring of

1230
00:46:41,670 --> 00:46:39,680
blue bright stars

1231
00:46:43,030 --> 00:46:41,680
so where we actually see a lot of star

1232
00:46:45,589 --> 00:46:43,040
formation

1233
00:46:48,230 --> 00:46:45,599
this is the same image of an image for

1234
00:46:49,750 --> 00:46:48,240
the same galaxy with the musical field

1235
00:46:51,910 --> 00:46:49,760
spectrograph and what you see here is

1236
00:46:52,710 --> 00:46:51,920
what we call a reconstructed image that

1237
00:46:55,430 --> 00:46:52,720
is

1238
00:46:57,750 --> 00:46:55,440

at every place in the field of view

1239
00:46:59,670 --> 00:46:57,760
all we have done is simply add up all

1240
00:47:01,589 --> 00:46:59,680
the light in the spectrum

1241
00:47:04,150 --> 00:47:01,599
and essentially attain what we call a

1242
00:47:06,950 --> 00:47:04,160
white light image

1243
00:47:09,430 --> 00:47:06,960
so you can see that the two images

1244
00:47:11,190 --> 00:47:09,440
correspond very well the spectral is the

1245
00:47:13,670 --> 00:47:11,200
spatial resolution is

1246
00:47:15,270 --> 00:47:13,680
clearly worse for the muse data because

1247
00:47:17,829 --> 00:47:15,280
they're from the ground

1248
00:47:20,069 --> 00:47:17,839
but they are you know still you can tell

1249
00:47:21,990 --> 00:47:20,079
a lot of details here

1250
00:47:25,190 --> 00:47:22,000
what you're now seeing here is on the

1251
00:47:27,190 --> 00:47:25,200
other end two particular measurements

1252
00:47:29,829 --> 00:47:27,200
on one in the middle what i'm showing

1253
00:47:31,750 --> 00:47:29,839
you is the stellar velocity field and on

1254
00:47:34,309 --> 00:47:31,760
the right the gas velocity field so what

1255
00:47:36,950 --> 00:47:34,319
we have done is that we have taken

1256
00:47:39,270 --> 00:47:36,960
the spectra at every place in the galaxy

1257
00:47:41,190 --> 00:47:39,280
sometime in order to gain signal to

1258
00:47:43,910 --> 00:47:41,200
noise what we have done is that we have

1259
00:47:45,750 --> 00:47:43,920
bind up with the spectra and added them

1260
00:47:47,750 --> 00:47:45,760
all up in these particular regions that

1261
00:47:48,870 --> 00:47:47,760
are a bit irregular which we call beans

1262
00:47:50,950 --> 00:47:48,880
here

1263
00:47:53,349 --> 00:47:50,960

to get good spectrum

1264
00:47:55,430 --> 00:47:53,359
and what we have obtained here is

1265
00:47:56,710 --> 00:47:55,440
simply we have measured the redshift or

1266
00:47:57,750 --> 00:47:56,720
blueshift

1267
00:47:59,910 --> 00:47:57,760
of the

1268
00:48:01,910 --> 00:47:59,920
absorption line in the stellar spectra

1269
00:48:04,230 --> 00:48:01,920
with respect to the expected

1270
00:48:07,589 --> 00:48:04,240
uh position at rest frame and the

1271
00:48:10,150 --> 00:48:07,599
falling third the velocity of the stars

1272
00:48:13,030 --> 00:48:10,160
in this side of the galaxy as opposed to

1273
00:48:14,950 --> 00:48:13,040
this one in red i'm showing you stars

1274
00:48:17,109 --> 00:48:14,960
that are receding from us

1275
00:48:19,190 --> 00:48:17,119
and in blue i'm showing you stars that

1276
00:48:23,030 --> 00:48:19,200
are approaching us so overall you can

1277
00:48:24,549 --> 00:48:23,040
think of this galaxy moving in this way

1278
00:48:27,030 --> 00:48:24,559
what you see on the right on the other

1279
00:48:29,430 --> 00:48:27,040
end is the same exercise but when i

1280
00:48:32,309 --> 00:48:29,440
actually focus in the spectra at the

1281
00:48:34,790 --> 00:48:32,319
emission line from the gas

1282
00:48:36,309 --> 00:48:34,800
in this case you can see that the

1283
00:48:37,270 --> 00:48:36,319
approach inside

1284
00:48:39,990 --> 00:48:37,280
actually

1285
00:48:41,750 --> 00:48:40,000
is where on the other side of the galaxy

1286
00:48:43,510 --> 00:48:41,760
so this means that this gas is actually

1287
00:48:45,510 --> 00:48:43,520
moving in this way

1288
00:48:47,349 --> 00:48:45,520

right so what we are actually seeing

1289
00:48:49,430 --> 00:48:47,359
here is gas

1290
00:48:51,829 --> 00:48:49,440
that is moving in the opposite direction

1291
00:48:53,990 --> 00:48:51,839
of the stars in this galaxy

1292
00:48:56,630 --> 00:48:54,000
which can only be interpreted as if this

1293
00:48:59,030 --> 00:48:56,640
gas was actually accreted as the result

1294
00:49:01,829 --> 00:48:59,040
of a merger of the galaxy

1295
00:49:03,990 --> 00:49:01,839
a small galaxy maybe a gas switch galaxy

1296
00:49:06,630 --> 00:49:04,000
that has now be completely destroyed

1297
00:49:08,549 --> 00:49:06,640
that this gas is left an acetyl in the

1298
00:49:10,790 --> 00:49:08,559
in the in the in the

1299
00:49:12,630 --> 00:49:10,800
in the plane of this galaxy

1300
00:49:14,950 --> 00:49:12,640
and is actually rotating the opposite

1301
00:49:16,390 --> 00:49:14,960
direction of the stars in other words

1302
00:49:19,109 --> 00:49:16,400
this is also

1303
00:49:23,030 --> 00:49:19,119
cannot be interpreted as gas

1304
00:49:25,190 --> 00:49:23,040
that was you know internal in the galaxy

1305
00:49:27,829 --> 00:49:25,200
as one would expect from stellar

1306
00:49:29,510 --> 00:49:27,839
evolution because stars we know they

1307
00:49:30,870 --> 00:49:29,520
explode

1308
00:49:33,430 --> 00:49:30,880
and release

1309
00:49:35,670 --> 00:49:33,440
the gas in the intestinal medium so if

1310
00:49:38,069 --> 00:49:35,680
this gas was of internal origin it will

1311
00:49:39,589 --> 00:49:38,079
as we rotate in the same direction so

1312
00:49:41,030 --> 00:49:39,599
what we are seeing here is direct

1313
00:49:42,390 --> 00:49:41,040

evidence with integral field

1314
00:49:44,710 --> 00:49:42,400
spectroscopy

1315
00:49:46,870 --> 00:49:44,720
of the beautiful past merger

1316
00:49:48,549 --> 00:49:46,880
in this galaxy is the remnants of this

1317
00:49:49,510 --> 00:49:48,559
merger

1318
00:49:51,670 --> 00:49:49,520
um

1319
00:49:53,589 --> 00:49:51,680
this is you know this was also possible

1320
00:49:55,910 --> 00:49:53,599
with long slick spectroscopy but here we

1321
00:49:57,430 --> 00:49:55,920
can really have and appreciate things in

1322
00:50:02,150 --> 00:49:57,440
greater detail

1323
00:50:07,589 --> 00:50:05,030
i also mentioned the star formation

1324
00:50:09,990 --> 00:50:07,599
history of a galaxy that we can try to

1325
00:50:13,589 --> 00:50:10,000
recover by understanding the different

1326
00:50:15,190 --> 00:50:13,599
mix of different stars of different ages

1327
00:50:18,150 --> 00:50:15,200
in a galaxy

1328
00:50:20,630 --> 00:50:18,160
and now this could be also linked to you

1329
00:50:23,670 --> 00:50:20,640
know the star formation process that

1330
00:50:25,510 --> 00:50:23,680
actually led to the growth of a galaxy

1331
00:50:28,150 --> 00:50:25,520
over the past so if we look in the

1332
00:50:30,870 --> 00:50:28,160
galaxy nearby and we reconstruct the

1333
00:50:34,309 --> 00:50:30,880
star formation history we can actually

1334
00:50:36,710 --> 00:50:34,319
understand how this galaxy formed

1335
00:50:38,710 --> 00:50:36,720
its stars in the past

1336
00:50:40,470 --> 00:50:38,720
so what you see is this nearby galaxy

1337
00:50:43,510 --> 00:50:40,480
that is quite big in the sky it's called

1338
00:50:45,430 --> 00:50:43,520

ngc 3115 and each of the square is

1339
00:50:47,990 --> 00:50:45,440
actually a muse field of view which is

1340
00:50:49,750 --> 00:50:48,000
basically one arcminix square

1341
00:50:52,630 --> 00:50:49,760
and

1342
00:50:55,109 --> 00:50:52,640
so what you see here long story short

1343
00:50:57,670 --> 00:50:55,119
is six panels and in each of these six

1344
00:50:58,870 --> 00:50:57,680
panels what you see is the amount of

1345
00:51:01,430 --> 00:50:58,880
stars

1346
00:51:03,349 --> 00:51:01,440
that for a at any given age so for

1347
00:51:06,069 --> 00:51:03,359
instance when you look at stars that are

1348
00:51:08,390 --> 00:51:06,079
between zero and four billion years old

1349
00:51:10,470 --> 00:51:08,400
we can call this you know young stars so

1350
00:51:11,990 --> 00:51:10,480
to speak you can see that they are all

1351
00:51:13,349 --> 00:51:12,000
in the disk

1352
00:51:15,510 --> 00:51:13,359
so

1353
00:51:17,270 --> 00:51:15,520
these are basically stars that formed

1354
00:51:19,109 --> 00:51:17,280
quite some time ago

1355
00:51:21,829 --> 00:51:19,119
but they formed

1356
00:51:23,750 --> 00:51:21,839
from gas that settled in the disk and

1357
00:51:24,710 --> 00:51:23,760
the story is more or less the same until

1358
00:51:26,950 --> 00:51:24,720
you go

1359
00:51:27,670 --> 00:51:26,960
at 10 giga years ago it's only when you

1360
00:51:30,150 --> 00:51:27,680
go

1361
00:51:31,829 --> 00:51:30,160
for stars that form you know

1362
00:51:33,190 --> 00:51:31,839
just a few

1363
00:51:35,349 --> 00:51:33,200

billion years one or two billion years

1364
00:51:37,349 --> 00:51:35,359
after the big bang that you see stars

1365
00:51:39,510 --> 00:51:37,359
that actually are distributed in the

1366
00:51:41,030 --> 00:51:39,520
so-called bulge atmospherical

1367
00:51:43,349 --> 00:51:41,040
distribution

1368
00:51:46,069 --> 00:51:43,359
so this is consistent with the idea that

1369
00:51:47,430 --> 00:51:46,079
you know in galaxies they form violently

1370
00:51:48,710 --> 00:51:47,440
in the past

1371
00:51:53,349 --> 00:51:48,720
and

1372
00:51:54,630 --> 00:51:53,359
distribution of stars in in in a more

1373
00:51:55,990 --> 00:51:54,640
spherical

1374
00:51:59,190 --> 00:51:56,000
and you know

1375
00:52:01,910 --> 00:51:59,200
flat uh fat

1376
00:52:04,470 --> 00:52:01,920
fetal regions which we call bounce

1377
00:52:07,349 --> 00:52:04,480
and only later there was a lot of star

1378
00:52:11,109 --> 00:52:07,359
formation more relaxed in the disk this

1379
00:52:14,710 --> 00:52:12,069
okay

1380
00:52:16,150 --> 00:52:14,720
so now let's come to

1381
00:52:19,030 --> 00:52:16,160
talk about

1382
00:52:20,950 --> 00:52:19,040
hubble and integral field spectroscopy

1383
00:52:23,829 --> 00:52:20,960
and i wanted to actually give you three

1384
00:52:26,630 --> 00:52:23,839
example i actually ended up choosing

1385
00:52:27,910 --> 00:52:26,640
of interaction fruitful interaction of

1386
00:52:29,270 --> 00:52:27,920
hubble

1387
00:52:30,950 --> 00:52:29,280
measurements and integer of your

1388
00:52:32,790 --> 00:52:30,960

spectroscopic measurement from the

1389
00:52:34,870 --> 00:52:32,800
ground where this could be very

1390
00:52:37,349 --> 00:52:34,880
complementary

1391
00:52:39,190 --> 00:52:37,359
so my first choice is about globular

1392
00:52:40,950 --> 00:52:39,200
clusters which i haven't talked about

1393
00:52:43,589 --> 00:52:40,960
yet

1394
00:52:45,190 --> 00:52:43,599
but globular clusters are very important

1395
00:52:46,470 --> 00:52:45,200
because they tell us

1396
00:52:49,510 --> 00:52:46,480
about

1397
00:52:52,150 --> 00:52:49,520
the assembly history of galaxies

1398
00:52:54,069 --> 00:52:52,160
so that those processes such as mergers

1399
00:52:57,589 --> 00:52:54,079
and in particular they tell us about the

1400
00:53:00,470 --> 00:52:57,599
assembly of the outskirts of galaxies

1401
00:53:02,870 --> 00:53:00,480
those faint diffuse extended regions

1402
00:53:04,870 --> 00:53:02,880
that we see in galaxies in particular in

1403
00:53:05,990 --> 00:53:04,880
very big galaxies such as the one you

1404
00:53:09,109 --> 00:53:06,000
see on the right

1405
00:53:10,950 --> 00:53:09,119
which is called m87 which is the central

1406
00:53:13,750 --> 00:53:10,960
most bright galaxies in the virgo

1407
00:53:16,470 --> 00:53:13,760
cluster which is also incidentally the

1408
00:53:17,589 --> 00:53:16,480
galaxy where we have actually imaged

1409
00:53:20,390 --> 00:53:17,599
the donut

1410
00:53:24,790 --> 00:53:22,150
the accretion disk around the center

1411
00:53:26,390 --> 00:53:24,800
black hole of this galaxy

1412
00:53:28,790 --> 00:53:26,400
and so all these little dots that you

1413
00:53:30,790 --> 00:53:28,800

see here are not stars in our galaxy

1414
00:53:32,150 --> 00:53:30,800
these are actually globular cluster in

1415
00:53:34,790 --> 00:53:32,160
m87

1416
00:53:38,150 --> 00:53:34,800
things that in our own milky way will

1417
00:53:40,230 --> 00:53:38,160
look as beautiful as this cluster here

1418
00:53:42,549 --> 00:53:40,240
so in our milky way we could actually

1419
00:53:45,190 --> 00:53:42,559
resolve all the stars

1420
00:53:47,190 --> 00:53:45,200
in this especially with hubble all the

1421
00:53:50,230 --> 00:53:47,200
star or

1422
00:53:51,670 --> 00:53:50,240
great number of stars

1423
00:53:59,910 --> 00:53:51,680
in

1424
00:54:02,630 --> 00:53:59,920
space telescope observation even just to

1425
00:54:05,190 --> 00:54:02,640
identify these clusters and these

1426
00:54:06,870 --> 00:54:05,200
distant galaxies

1427
00:54:09,349 --> 00:54:06,880
so why are these globular clusters

1428
00:54:11,430 --> 00:54:09,359
important why do they tell us something

1429
00:54:12,630 --> 00:54:11,440
about the story of the assembly story of

1430
00:54:14,230 --> 00:54:12,640
galaxies

1431
00:54:16,790 --> 00:54:14,240
well it turns out that global cluster

1432
00:54:19,430 --> 00:54:16,800
comes in two kind of flavors

1433
00:54:22,549 --> 00:54:19,440
they're all made of all stars and yet

1434
00:54:25,750 --> 00:54:22,559
some are bluer than others so they come

1435
00:54:28,069 --> 00:54:25,760
if you want into a red and blue favor

1436
00:54:30,470 --> 00:54:28,079
now normally as i mentioned before a

1437
00:54:32,390 --> 00:54:30,480
blue star would be a young star

1438
00:54:35,750 --> 00:54:32,400

so a cluster of blue stars like a

1439
00:54:37,190 --> 00:54:35,760
pleiades is a cluster of young stars but

1440
00:54:39,030 --> 00:54:37,200
that's not the case for globular

1441
00:54:40,230 --> 00:54:39,040
clusters so in the case of globular

1442
00:54:42,710 --> 00:54:40,240
clusters

1443
00:54:45,510 --> 00:54:42,720
what the color is actually telling us

1444
00:54:48,390 --> 00:54:45,520
is a more subtle effect which is telling

1445
00:54:49,190 --> 00:54:48,400
us about the metal abundance

1446
00:54:51,910 --> 00:54:49,200
so

1447
00:54:53,030 --> 00:54:51,920
when a cluster is actually poor in

1448
00:54:54,870 --> 00:54:53,040
metals

1449
00:54:56,710 --> 00:54:54,880
it appears bluer

1450
00:54:58,710 --> 00:54:56,720
one is more red and one is rather on the

1451
00:55:01,109 --> 00:54:58,720
other end it means that it is more

1452
00:55:03,750 --> 00:55:01,119
abundant in metals

1453
00:55:05,990 --> 00:55:03,760
and in turns this tells us something on

1454
00:55:07,990 --> 00:55:06,000
where this globular cluster may have

1455
00:55:10,069 --> 00:55:08,000
formed

1456
00:55:12,630 --> 00:55:10,079
if they are rich in metals it means that

1457
00:55:14,870 --> 00:55:12,640
they are formed in more massive galaxies

1458
00:55:17,510 --> 00:55:14,880
originally okay those galaxies may not

1459
00:55:19,750 --> 00:55:17,520
be long may no longer be around

1460
00:55:22,150 --> 00:55:19,760
this is where those clusters may have

1461
00:55:24,390 --> 00:55:22,160
formed or they may not be around in the

1462
00:55:27,109 --> 00:55:24,400
way we know them now

1463
00:55:29,750 --> 00:55:27,119

why is that is because

1464
00:55:31,430 --> 00:55:29,760
when you have galaxy and you have stars

1465
00:55:34,870 --> 00:55:31,440
forming in it and you have stars

1466
00:55:38,150 --> 00:55:34,880
exploding in it and releasing those

1467
00:55:40,309 --> 00:55:38,160
their gas in the interstellar medium

1468
00:55:43,030 --> 00:55:40,319
those stars then refor these gas then

1469
00:55:45,430 --> 00:55:43,040
reforming to new stars and the process

1470
00:55:46,950 --> 00:55:45,440
continues and every time what you have

1471
00:55:49,270 --> 00:55:46,960
at the center of stars is that you

1472
00:55:51,430 --> 00:55:49,280
produce more and more metals

1473
00:55:54,630 --> 00:55:51,440
and so as the story goes on as long as

1474
00:55:56,870 --> 00:55:54,640
you can retain the gas in a galaxy the

1475
00:55:59,109 --> 00:55:56,880
interstellar medium gets more and more

1476
00:56:02,069 --> 00:55:59,119
enriched in metals and that gets

1477
00:56:04,230 --> 00:56:02,079
imprinted in the style in the stars that

1478
00:56:07,109 --> 00:56:04,240
form in that galaxy and the same applies

1479
00:56:08,150 --> 00:56:07,119
then if that particular globular cluster

1480
00:56:10,390 --> 00:56:08,160
formed

1481
00:56:12,950 --> 00:56:10,400
from a very matter-rich interstellar

1482
00:56:14,789 --> 00:56:12,960
medium of a massive galaxy

1483
00:56:16,549 --> 00:56:14,799
in a dwarf galaxy

1484
00:56:18,789 --> 00:56:16,559
then basically the feedback process i

1485
00:56:19,910 --> 00:56:18,799
mentioned before in particular star

1486
00:56:21,510 --> 00:56:19,920
formation

1487
00:56:23,750 --> 00:56:21,520
are very efficient because they can

1488
00:56:25,430 --> 00:56:23,760

drive out very quickly

1489
00:56:27,589 --> 00:56:25,440
the gas out of the galaxy because the

1490
00:56:28,549 --> 00:56:27,599
galaxy is too small to gravitational

1491
00:56:30,789 --> 00:56:28,559
retain

1492
00:56:35,030 --> 00:56:30,799
its metals it's gas

1493
00:56:38,150 --> 00:56:35,040
and so in that case the clusters formed

1494
00:56:40,789 --> 00:56:38,160
from a very metal pool environment

1495
00:56:43,349 --> 00:56:40,799
and so they are blue

1496
00:56:45,910 --> 00:56:43,359
and this connects indeed to the idea

1497
00:56:47,750 --> 00:56:45,920
that in galaxy formation you may have a

1498
00:56:50,710 --> 00:56:47,760
two-phase process

1499
00:56:54,870 --> 00:56:50,720
where you have an in-situ formation

1500
00:56:58,150 --> 00:56:54,880
of where stars form in a in the same

1501
00:56:59,190 --> 00:56:58,160
place essentially okay in a galaxy over

1502
00:57:00,309 --> 00:56:59,200
time

1503
00:57:02,630 --> 00:57:00,319
and then

1504
00:57:04,470 --> 00:57:02,640
the the there is metal enrichment going

1505
00:57:05,510 --> 00:57:04,480
on and the formation of red globular

1506
00:57:07,990 --> 00:57:05,520
cluster

1507
00:57:10,829 --> 00:57:08,000
and you have the accretion process

1508
00:57:14,710 --> 00:57:10,839
in particular for metapoor dwarf

1509
00:57:16,710 --> 00:57:14,720
galaxies okay and these two processes

1510
00:57:19,190 --> 00:57:16,720
the relics of these two process may

1511
00:57:22,549 --> 00:57:19,200
still be imprinted in the areas of

1512
00:57:24,710 --> 00:57:22,559
galaxies and we can trace this

1513
00:57:27,589 --> 00:57:24,720

in particular from the globular cluster

1514
00:57:29,510 --> 00:57:27,599
population what was more important red

1515
00:57:30,870 --> 00:57:29,520
or blue formation

1516
00:57:33,750 --> 00:57:30,880
it turns out

1517
00:57:35,750 --> 00:57:33,760
that in most globular clusters in most

1518
00:57:40,230 --> 00:57:35,760
galaxies what we see

1519
00:57:41,510 --> 00:57:40,240
is a distribution of blue and red

1520
00:57:43,670 --> 00:57:41,520
clusters

1521
00:57:45,349 --> 00:57:43,680
that appears to be double picked as if

1522
00:57:47,910 --> 00:57:45,359
there are indeed two distinct

1523
00:57:49,829 --> 00:57:47,920
populations so that means that the two

1524
00:57:51,430 --> 00:57:49,839
processes were indeed present and

1525
00:57:53,349 --> 00:57:51,440
important

1526
00:57:55,829 --> 00:57:53,359
and this is something that we can only

1527
00:57:58,630 --> 00:57:55,839
be done in external galaxies with hubble

1528
00:58:00,390 --> 00:57:58,640
as i said hubble is key to recognize

1529
00:58:03,109 --> 00:58:00,400
this globular cluster which have the

1530
00:58:05,190 --> 00:58:03,119
typical size of maybe 10 parsecs so

1531
00:58:06,150 --> 00:58:05,200
they're very very small at most 10

1532
00:58:09,510 --> 00:58:06,160
percent

1533
00:58:11,510 --> 00:58:09,520
they're very very small um subarc second

1534
00:58:14,710 --> 00:58:11,520
so you really need um

1535
00:58:17,750 --> 00:58:14,720
hubble to see these um these clusters

1536
00:58:20,710 --> 00:58:17,760
and you also have immediately for free

1537
00:58:22,870 --> 00:58:20,720
if you observe these um these clusters

1538
00:58:24,630 --> 00:58:22,880

these images in two filters you can

1539
00:58:26,710 --> 00:58:24,640
determine the color and this is what

1540
00:58:28,390 --> 00:58:26,720
exactly has been done

1541
00:58:31,589 --> 00:58:28,400
uh in the

1542
00:58:33,510 --> 00:58:31,599
acs wide field camera surveys

1543
00:58:36,480 --> 00:58:33,520
uh of the vehicle cluster for instance

1544
00:58:38,390 --> 00:58:36,490
this is worked by peter jordan in 2015.

1545
00:58:40,230 --> 00:58:38,400
[Music]

1546
00:58:41,750 --> 00:58:40,240
and

1547
00:58:43,990 --> 00:58:41,760
but this is

1548
00:58:45,109 --> 00:58:44,000
the story as far as only colors are

1549
00:58:47,589 --> 00:58:45,119
concerned

1550
00:58:49,750 --> 00:58:47,599
what if we could measure directly the

1551
00:58:53,510 --> 00:58:49,760
metallicity of these globular clusters

1552
00:58:54,630 --> 00:58:53,520
to do this we will actually need spectra

1553
00:58:56,230 --> 00:58:54,640
okay

1554
00:58:59,270 --> 00:58:56,240
and this is what is possible with

1555
00:59:02,150 --> 00:58:59,280
integrative spectroscopy and with muse

1556
00:59:03,750 --> 00:59:02,160
so this is work that katja fyron did a

1557
00:59:07,349 --> 00:59:03,760
couple of years ago

1558
00:59:08,710 --> 00:59:07,359
so what we did there is simply

1559
00:59:09,910 --> 00:59:08,720
to take

1560
00:59:12,470 --> 00:59:09,920
use data

1561
00:59:15,190 --> 00:59:12,480
of galaxies for which

1562
00:59:17,910 --> 00:59:15,200
hubble had already identified

1563
00:59:20,069 --> 00:59:17,920

a lot of globular clusters and extracted

1564
00:59:22,549 --> 00:59:20,079
spectra where possible around the

1565
00:59:24,789 --> 00:59:22,559
location of this globular cluster as

1566
00:59:26,789 --> 00:59:24,799
indicated by hubble so that's the key

1567
00:59:28,870 --> 00:59:26,799
role of hubble is basically to tell us

1568
00:59:30,309 --> 00:59:28,880
where the cluster were

1569
00:59:31,990 --> 00:59:30,319
and the spectral that you see here on

1570
00:59:33,829 --> 00:59:32,000
the right you know sometimes they're

1571
00:59:36,549 --> 00:59:33,839
good sometimes they're not that good in

1572
00:59:38,230 --> 00:59:36,559
terms of quality but we can still

1573
00:59:40,549 --> 00:59:38,240
you know um

1574
00:59:43,990 --> 00:59:40,559
fit them with models

1575
00:59:45,589 --> 00:59:44,000
where you know the abundance of metals

1576
00:59:47,990 --> 00:59:45,599
or the age

1577
00:59:49,670 --> 00:59:48,000
of the clusters can be changed and

1578
00:59:51,750 --> 00:59:49,680
essentially you work out what is the

1579
00:59:54,549 --> 00:59:51,760
best agent what is the best metal

1580
00:59:58,630 --> 00:59:54,559
content or what we call metalistic

1581
01:00:01,990 --> 00:59:58,640
and in the end uh estimate directly the

1582
01:00:03,750 --> 01:00:02,000
metallicity of these clusters

1583
01:00:06,630 --> 01:00:03,760
and it turned out that the relation

1584
01:00:08,870 --> 01:00:06,640
between the metallicity of the clusters

1585
01:00:10,789 --> 01:00:08,880
and the color of the cluster is not a

1586
01:00:12,230 --> 01:00:10,799
one-to-one relation it's not even a

1587
01:00:14,630 --> 01:00:12,240
linear relation

1588
01:00:16,470 --> 01:00:14,640

it's a more complicated relation

1589
01:00:18,150 --> 01:00:16,480
is what we call a non-linear relation

1590
01:00:20,630 --> 01:00:18,160
that essentially tells you that you

1591
01:00:23,030 --> 01:00:20,640
cannot simply translate one from the

1592
01:00:25,190 --> 01:00:23,040
other you cannot just go from color

1593
01:00:28,069 --> 01:00:25,200
to metal content straight away there

1594
01:00:29,750 --> 01:00:28,079
would be a change when you do that

1595
01:00:31,430 --> 01:00:29,760
and in fact this is the case of one

1596
01:00:33,589 --> 01:00:31,440
particular galaxy the galaxy i showed

1597
01:00:35,829 --> 01:00:33,599
you before

1598
01:00:38,789 --> 01:00:35,839
this is the distribution of colors

1599
01:00:40,470 --> 01:00:38,799
and the metal distribution is completely

1600
01:00:41,990 --> 01:00:40,480
different

1601
01:00:45,270 --> 01:00:42,000
and in general when you do this

1602
01:00:47,190 --> 01:00:45,280
translation things get more complicated

1603
01:00:48,789 --> 01:00:47,200
and so that's an example that may not be

1604
01:00:50,150 --> 01:00:48,799
super exciting in the sense that it

1605
01:00:52,309 --> 01:00:50,160
doesn't lead to a clear result but it's

1606
01:00:55,270 --> 01:00:52,319
very important because it tells you that

1607
01:00:57,349 --> 01:00:55,280
colors are not all and you need spectra

1608
01:01:00,150 --> 01:00:57,359
and integrals with spectroscopy will be

1609
01:01:03,589 --> 01:01:00,160
very important to you know finally crack

1610
01:01:08,069 --> 01:01:06,309
ah on another example

1611
01:01:09,349 --> 01:01:08,079
let me talk about supermassive black

1612
01:01:11,670 --> 01:01:09,359
holes

1613
01:01:14,150 --> 01:01:11,680

so thanks to

1614
01:01:16,309 --> 01:01:14,160
hubble space telescope in particular we

1615
01:01:18,230 --> 01:01:16,319
now know that there are supermassive

1616
01:01:20,789 --> 01:01:18,240
black holes nearly at the center of

1617
01:01:22,549 --> 01:01:20,799
every galaxy that we looked at

1618
01:01:24,549 --> 01:01:22,559
we know that there is a tight relation

1619
01:01:27,109 --> 01:01:24,559
between the mass of the black hole and

1620
01:01:29,510 --> 01:01:27,119
the mass of the galaxy big black holes

1621
01:01:31,510 --> 01:01:29,520
live in big galaxies small black holes

1622
01:01:33,030 --> 01:01:31,520
more in small galaxies it's a very

1623
01:01:35,030 --> 01:01:33,040
important relation

1624
01:01:37,829 --> 01:01:35,040
because it hints at the fact that

1625
01:01:39,430 --> 01:01:37,839
galaxies and black hole evolve together

1626
01:01:41,349 --> 01:01:39,440
and in fact we see

1627
01:01:44,230 --> 01:01:41,359
in the plot i showed you before when we

1628
01:01:45,670 --> 01:01:44,240
look back in time we see that black hole

1629
01:01:47,109 --> 01:01:45,680
grew

1630
01:01:51,670 --> 01:01:47,119
in a parallel way

1631
01:01:55,349 --> 01:01:53,670
you need black you need very high

1632
01:01:58,390 --> 01:01:55,359
resolution to

1633
01:02:00,309 --> 01:01:58,400
really measure the mass of a black hole

1634
01:02:02,950 --> 01:02:00,319
and that was very important

1635
01:02:05,589 --> 01:02:02,960
that we had hubble for that

1636
01:02:07,349 --> 01:02:05,599
and more mass measurement are needed to

1637
01:02:10,069 --> 01:02:07,359
really understand the link between black

1638
01:02:12,390 --> 01:02:10,079

holes and galaxies

1639
01:02:15,109 --> 01:02:12,400
as i said black hubble played a big part

1640
01:02:18,710 --> 01:02:15,119
and so here is an example of how you can

1641
01:02:20,950 --> 01:02:18,720
measure the mass of a black hole

1642
01:02:23,109 --> 01:02:20,960
in the case of hubble we only have a

1643
01:02:24,950 --> 01:02:23,119
long-sleeve spectroscopy on humble we

1644
01:02:26,150 --> 01:02:24,960
also have sleepless spectroscopy as i

1645
01:02:27,910 --> 01:02:26,160
said before

1646
01:02:29,829 --> 01:02:27,920
this instrument in particular is called

1647
01:02:34,870 --> 01:02:29,839
this

1648
01:02:37,510 --> 01:02:34,880
stitch and then you can see here how the

1649
01:02:39,070 --> 01:02:37,520
in particular this is the the position

1650
01:02:40,309 --> 01:02:39,080
in a spectrum

1651
01:02:41,510 --> 01:02:40,319
[Music]

1652
01:02:43,670 --> 01:02:41,520
um

1653
01:02:45,510 --> 01:02:43,680
or if you want it is the velocity of a

1654
01:02:47,510 --> 01:02:45,520
particular emission line so this is

1655
01:02:49,430 --> 01:02:47,520
tracing the motion of the gas near the

1656
01:02:51,670 --> 01:02:49,440
center of the galaxy

1657
01:02:53,430 --> 01:02:51,680
and as we come from outer part towards

1658
01:02:56,309 --> 01:02:53,440
the near part what we see is that the

1659
01:02:58,549 --> 01:02:56,319
gas velocity suddenly increased so here

1660
01:03:01,029 --> 01:02:58,559
you have a very strong blue shift and

1661
01:03:03,029 --> 01:03:01,039
here we have a very strong redshift

1662
01:03:04,549 --> 01:03:03,039
and then the signal gets mixed in the

1663
01:03:05,670 --> 01:03:04,559

center where we don't have enough

1664
01:03:07,670 --> 01:03:05,680
resolution

1665
01:03:09,670 --> 01:03:07,680
but what this is showing you is the

1666
01:03:12,789 --> 01:03:09,680
typical trend

1667
01:03:13,829 --> 01:03:12,799
that reminds you of the keplerian curve

1668
01:03:15,670 --> 01:03:13,839
of

1669
01:03:18,390 --> 01:03:15,680
planets around the sun so what you see

1670
01:03:20,309 --> 01:03:18,400
is that the gas clouds in the in this

1671
01:03:21,670 --> 01:03:20,319
galaxy are behaving just like the

1672
01:03:24,230 --> 01:03:21,680
planets around

1673
01:03:26,309 --> 01:03:24,240
the sun so they are moving faster and

1674
01:03:28,789 --> 01:03:26,319
faster as they get closer to something

1675
01:03:31,029 --> 01:03:28,799
that is very massive and everything and

1676
01:03:33,109 --> 01:03:31,039
all these mass things in the center and

1677
01:03:34,309 --> 01:03:33,119
if you do the math you actually work out

1678
01:03:37,190 --> 01:03:34,319
that this actually to be a very

1679
01:03:40,390 --> 01:03:37,200
concentrated dark object with a very big

1680
01:03:42,829 --> 01:03:40,400
mass of a few times 10 10 to the 7 10 to

1681
01:03:46,150 --> 01:03:42,839
the eighth if i remember

1682
01:03:50,150 --> 01:03:46,160
correctly masses

1683
01:03:53,589 --> 01:03:51,589
now

1684
01:03:55,270 --> 01:03:53,599
this was an example of when you have a

1685
01:03:57,670 --> 01:03:55,280
very nice and well behaved gas

1686
01:03:59,670 --> 01:03:57,680
kinematics and in this case you can just

1687
01:04:01,430 --> 01:03:59,680
use the hubble space telescope

1688
01:04:04,549 --> 01:04:01,440

observation because all you need to know

1689
01:04:06,230 --> 01:04:04,559
is how the gas moves nearby

1690
01:04:08,630 --> 01:04:06,240
well-behaved gas on the other hand is

1691
01:04:10,630 --> 01:04:08,640
very rare in galaxies what we are not

1692
01:04:12,069 --> 01:04:10,640
short of is stars

1693
01:04:14,950 --> 01:04:12,079
but these actually move in very

1694
01:04:16,150 --> 01:04:14,960
complicated ways which require careful

1695
01:04:17,589 --> 01:04:16,160
modeling

1696
01:04:20,390 --> 01:04:17,599
um

1697
01:04:22,789 --> 01:04:20,400
and furthermore you have stars that span

1698
01:04:24,789 --> 01:04:22,799
both time close and far away from the

1699
01:04:27,190 --> 01:04:24,799
center so if you really want to

1700
01:04:29,349 --> 01:04:27,200
understand the galaxy the

1701
01:04:31,349 --> 01:04:29,359
dynamics and now this is affected you

1702
01:04:33,750 --> 01:04:31,359
know by the central black hole

1703
01:04:35,910 --> 01:04:33,760
overall you need in fact to map the

1704
01:04:37,750 --> 01:04:35,920
entire kinematics of the galaxy or at

1705
01:04:40,069 --> 01:04:37,760
least in the very central region very

1706
01:04:43,109 --> 01:04:40,079
carefully and have some constraint on

1707
01:04:45,109 --> 01:04:43,119
our star still move in the outer region

1708
01:04:46,950 --> 01:04:45,119
so you need integral field spectroscopy

1709
01:04:49,190 --> 01:04:46,960
also here

1710
01:04:51,270 --> 01:04:49,200
one of the first examples where we could

1711
01:04:53,910 --> 01:04:51,280
combine integral phase spectroscopy in

1712
01:04:56,789 --> 01:04:53,920
the outer part and hubble space

1713
01:04:58,950 --> 01:04:56,799

telescope spectroscopy in the center was

1714
01:05:00,549 --> 01:04:58,960
in the observation of and the black hole

1715
01:05:02,710 --> 01:05:00,559
mass measurement of this tiny little

1716
01:05:04,549 --> 01:05:02,720
galaxy that is called m32

1717
01:05:06,230 --> 01:05:04,559
it is actually a very important galaxy

1718
01:05:07,589 --> 01:05:06,240
because the black hole in this galaxy is

1719
01:05:14,230 --> 01:05:07,599
very small

1720
01:05:16,950 --> 01:05:14,240
important galaxy in the relation between

1721
01:05:18,710 --> 01:05:16,960
black hole mass and galaxy mass

1722
01:05:20,390 --> 01:05:18,720
because the extremes

1723
01:05:23,190 --> 01:05:20,400
in a correlation are very important to

1724
01:05:25,510 --> 01:05:23,200
really determine the correct slope of a

1725
01:05:27,750 --> 01:05:25,520
correlation

1726
01:05:29,990 --> 01:05:27,760
so these combine hubble space telescope

1727
01:05:32,710 --> 01:05:30,000
images and data

1728
01:05:34,630 --> 01:05:32,720
with an integral integrals with

1729
01:05:35,589 --> 01:05:34,640
field spectroscopic data measurement

1730
01:05:37,589 --> 01:05:35,599
from

1731
01:05:40,549 --> 01:05:37,599
actually a spectrograph that which will

1732
01:05:42,870 --> 01:05:40,559
cause which was called sauron

1733
01:05:44,549 --> 01:05:42,880
it's a very complicated acronym

1734
01:05:46,549 --> 01:05:44,559
but it was simply justified because

1735
01:05:47,430 --> 01:05:46,559
people in that team really like tolkien

1736
01:05:49,190 --> 01:05:47,440
like me

1737
01:05:51,829 --> 01:05:49,200
and what you see here is basically

1738
01:05:53,670 --> 01:05:51,839

sauron looking through his orb

1739
01:05:57,829 --> 01:05:53,680
of a stolen volunteer

1740
01:06:02,710 --> 01:06:00,069
and so here's what we can find here we

1741
01:06:04,710 --> 01:06:02,720
have the stis long-sleeve kinematics

1742
01:06:08,309 --> 01:06:04,720
what you see here is the velocity curve

1743
01:06:10,549 --> 01:06:08,319
or galaxy and what you see is also the

1744
01:06:13,829 --> 01:06:10,559
velocity dispersion how random is the

1745
01:06:15,829 --> 01:06:13,839
motion of the stars as you move from the

1746
01:06:17,589 --> 01:06:15,839
out outer part of the nucleus towards

1747
01:06:19,670 --> 01:06:17,599
the very center and things get very

1748
01:06:22,069 --> 01:06:19,680
messy and very fast

1749
01:06:24,069 --> 01:06:22,079
near the center because stars do not

1750
01:06:25,990 --> 01:06:24,079
want to fall into the black hole or put

1751
01:06:28,470 --> 01:06:26,000
another way only the stars that move

1752
01:06:30,710 --> 01:06:28,480
very fast have not fallen yet into the

1753
01:06:32,870 --> 01:06:30,720
black hole

1754
01:06:35,589 --> 01:06:32,880
and this very central measurements were

1755
01:06:38,230 --> 01:06:35,599
combined with integral field data for

1756
01:06:39,670 --> 01:06:38,240
the kinematic at larger radii and these

1757
01:06:44,069 --> 01:06:39,680
are the data

1758
01:06:46,390 --> 01:06:44,079
the model and this actually beautiful

1759
01:06:48,710 --> 01:06:46,400
map is actually the model

1760
01:06:50,950 --> 01:06:48,720
for this uh velocity and velocity

1761
01:06:54,150 --> 01:06:50,960
dispersion field and this is work that

1762
01:06:55,270 --> 01:06:54,160
was done 20 years ago now gosh by alan

1763
01:06:57,510 --> 01:06:55,280

veron

1764
01:06:58,870 --> 01:06:57,520
it was one of the first if not the first

1765
01:07:01,750 --> 01:06:58,880
combination of integral field

1766
01:07:03,829 --> 01:07:01,760
spectroscopy and hubble space telescope

1767
01:07:06,309 --> 01:07:03,839
spectroscopy since then actually

1768
01:07:08,390 --> 01:07:06,319
interestingly this exercise has not been

1769
01:07:10,470 --> 01:07:08,400
repeated very much because

1770
01:07:12,710 --> 01:07:10,480
of the advent of adapt adaptive

1771
01:07:14,630 --> 01:07:12,720
observations these are observations that

1772
01:07:16,069 --> 01:07:14,640
you can do from the ground where you can

1773
01:07:19,029 --> 01:07:16,079
correct for the blurring of the

1774
01:07:21,910 --> 01:07:19,039
atmosphere and basically get

1775
01:07:24,549 --> 01:07:21,920
similar or not that you know of similar

1776
01:07:26,829 --> 01:07:24,559
quality not quite as good as other

1777
01:07:30,150 --> 01:07:26,839
spectroscopic measurements or even

1778
01:07:32,710 --> 01:07:30,160
images um

1779
01:07:34,069 --> 01:07:32,720
so for instance here's an example of how

1780
01:07:36,630 --> 01:07:34,079
this was done

1781
01:07:37,750 --> 01:07:36,640
for uh

1782
01:07:39,829 --> 01:07:37,760
you know

1783
01:07:42,230 --> 01:07:39,839
measuring the motion of the very central

1784
01:07:43,510 --> 01:07:42,240
stars of our milky way close to the

1785
01:07:45,910 --> 01:07:43,520
center

1786
01:07:48,230 --> 01:07:45,920
and you know this is the an example of

1787
01:07:51,109 --> 01:07:48,240
how the adaptive optic works

1788
01:07:53,270 --> 01:07:51,119

it makes stars sharper

1789
01:07:55,430 --> 01:07:53,280
and you know the image is sharper and

1790
01:07:56,470 --> 01:07:55,440
you actually can see more stars in the

1791
01:07:58,390 --> 01:07:56,480
process

1792
01:08:00,950 --> 01:07:58,400
and when you follow the

1793
01:08:03,190 --> 01:08:00,960
motion of the stars over the years

1794
01:08:04,870 --> 01:08:03,200
you actually infer the presence of

1795
01:08:06,470 --> 01:08:04,880
something big in the center that is

1796
01:08:08,309 --> 01:08:06,480
pulling the stars around

1797
01:08:14,549 --> 01:08:08,319
and this is what's led also to the nobel

1798
01:08:18,709 --> 01:08:17,030
so even when you have this adaptive

1799
01:08:21,510 --> 01:08:18,719
optic observations

1800
01:08:24,070 --> 01:08:21,520
hubble is still very important because

1801
01:08:27,829 --> 01:08:24,080
hubble is needed to give you the best

1802
01:08:30,550 --> 01:08:27,839
possible images and you use these images

1803
01:08:31,440 --> 01:08:30,560
to infer in turn what is the stellar

1804
01:08:32,789 --> 01:08:31,450
distribution

1805
01:08:34,229 --> 01:08:32,799
[Music]

1806
01:08:36,390 --> 01:08:34,239
um

1807
01:08:38,709 --> 01:08:36,400
the stellar distribution

1808
01:08:40,789 --> 01:08:38,719
and stellar mass all the way to the

1809
01:08:43,110 --> 01:08:40,799
center where you actually want to do a

1810
01:08:45,349 --> 01:08:43,120
fine balance of actually telling what is

1811
01:08:47,749 --> 01:08:45,359
the relative contribution of

1812
01:08:49,030 --> 01:08:47,759
to the gravitational potential of your

1813
01:08:50,470 --> 01:08:49,040

putative

1814
01:08:52,789 --> 01:08:50,480
central black hole

1815
01:08:54,470 --> 01:08:52,799
and of the stars

1816
01:08:55,749 --> 01:08:54,480
so you want to be able to really know

1817
01:08:58,309 --> 01:08:55,759
what is the contribution to the

1818
01:09:01,030 --> 01:08:58,319
gravitational potential of the stars

1819
01:09:03,269 --> 01:09:01,040
only this is why you need hst images

1820
01:09:04,870 --> 01:09:03,279
because the ground-based adaptive optic

1821
01:09:07,510 --> 01:09:04,880
observation do not give you actually

1822
01:09:09,030 --> 01:09:07,520
quite as good the spectre is the spatial

1823
01:09:10,550 --> 01:09:09,040
resolution of

1824
01:09:12,070 --> 01:09:10,560
of a hubble

1825
01:09:14,149 --> 01:09:12,080
but what is also very important with

1826
01:09:15,829 --> 01:09:14,159
hubble is that because you can you can

1827
01:09:17,510 --> 01:09:15,839
use these images

1828
01:09:19,749 --> 01:09:17,520
to actually understand what is the

1829
01:09:20,950 --> 01:09:19,759
quality of your adaptive optic

1830
01:09:23,030 --> 01:09:20,960
correction

1831
01:09:24,789 --> 01:09:23,040
frank also mentioned this for me thank

1832
01:09:28,630 --> 01:09:24,799
you very much when he talked about the

1833
01:09:32,149 --> 01:09:28,640
psf psf stands for point spread function

1834
01:09:34,789 --> 01:09:32,159
so this tells you how how much the light

1835
01:09:36,789 --> 01:09:34,799
from the point source is distributed out

1836
01:09:39,430 --> 01:09:36,799
in space

1837
01:09:41,590 --> 01:09:39,440
and this is also important because we

1838
01:09:44,630 --> 01:09:41,600

actually need to know exactly

1839
01:09:46,950 --> 01:09:44,640
this detail when we build our model for

1840
01:09:48,870 --> 01:09:46,960
the motion of the stars and the gaps or

1841
01:09:49,829 --> 01:09:48,880
in this case just the stars

1842
01:09:51,510 --> 01:09:49,839
and we

1843
01:09:53,110 --> 01:09:51,520
convolve these models with this point

1844
01:09:54,630 --> 01:09:53,120
flux function to actually make good

1845
01:09:56,310 --> 01:09:54,640
prediction for the observed stellar

1846
01:09:58,149 --> 01:09:56,320
kinematics

1847
01:09:59,750 --> 01:09:58,159
but to know exactly what is the point

1848
01:10:01,189 --> 01:09:59,760
spread function

1849
01:10:03,669 --> 01:10:01,199
we can use a

1850
01:10:05,350 --> 01:10:03,679
point source as a reference or when we

1851
01:10:07,110 --> 01:10:05,360
don't have this or if we want to

1852
01:10:09,430 --> 01:10:07,120
actually monitor the points per function

1853
01:10:12,149 --> 01:10:09,440
near the center of a galaxy we can

1854
01:10:13,030 --> 01:10:12,159
actually use as a reference the hubble

1855
01:10:15,910 --> 01:10:13,040
image

1856
01:10:18,550 --> 01:10:15,920
and convolve this maybe with a dam shell

1857
01:10:21,750 --> 01:10:18,560
with a psf model until we actually have

1858
01:10:23,830 --> 01:10:21,760
a perfect match to our low resolution

1859
01:10:26,870 --> 01:10:23,840
muse images

1860
01:10:28,870 --> 01:10:26,880
so hubble space telescope is

1861
01:10:31,110 --> 01:10:28,880
and high resolution images

1862
01:10:33,830 --> 01:10:31,120
from future space telescope will still

1863
01:10:35,510 --> 01:10:33,840

be key to the modeling

1864
01:10:38,149 --> 01:10:35,520
of the central region of the galaxy and

1865
01:10:39,990 --> 01:10:38,159
the determination of black holes

1866
01:10:42,390 --> 01:10:40,000
i want to conclude now with a couple of

1867
01:10:45,030 --> 01:10:42,400
words on eastern galaxies

1868
01:10:46,709 --> 01:10:45,040
so hubble was pivotal in imaging

1869
01:10:49,750 --> 01:10:46,719
galaxies in the distant universe with

1870
01:10:52,630 --> 01:10:49,760
surveys like the hubble ultra deep field

1871
01:10:53,910 --> 01:10:52,640
we know that and i mentioned this before

1872
01:10:54,870 --> 01:10:53,920
as well

1873
01:10:57,270 --> 01:10:54,880
um

1874
01:10:59,990 --> 01:10:57,280
however if you this this gives us a lot

1875
01:11:01,910 --> 01:11:00,000
of of detailed images of galaxies

1876
01:11:04,950 --> 01:11:01,920
incredibly far away

1877
01:11:06,470 --> 01:11:04,960
um but we don't have great spectra we

1878
01:11:08,630 --> 01:11:06,480
don't actually get a spectra for this

1879
01:11:09,750 --> 01:11:08,640
galaxy so we don't really have spectra

1880
01:11:12,149 --> 01:11:09,760
properties

1881
01:11:13,910 --> 01:11:12,159
and we you know we can only infer some

1882
01:11:17,110 --> 01:11:13,920
of the estimate

1883
01:11:18,070 --> 01:11:17,120
star formation rates in these galaxies

1884
01:11:20,550 --> 01:11:18,080
um

1885
01:11:22,550 --> 01:11:20,560
and in terms of redshift we actually

1886
01:11:24,310 --> 01:11:22,560
have to follow this up with spectroscopy

1887
01:11:25,830 --> 01:11:24,320
observation to really know at the

1888
01:11:29,110 --> 01:11:25,840

velocity of which are they they're

1889
01:11:30,870 --> 01:11:29,120
moving and then in further distances

1890
01:11:32,550 --> 01:11:30,880
so

1891
01:11:34,790 --> 01:11:32,560
the best way to do this is using

1892
01:11:36,630 --> 01:11:34,800
integral field spectroscopy so you just

1893
01:11:38,149 --> 01:11:36,640
take a you know place your integral of

1894
01:11:40,390 --> 01:11:38,159
your spectrograph here and you get

1895
01:11:42,470 --> 01:11:40,400
spectra everywhere in the field so

1896
01:11:44,070 --> 01:11:42,480
we just have to wait another 10 years

1897
01:11:46,070 --> 01:11:44,080
after the hubble tech field and finally

1898
01:11:48,550 --> 01:11:46,080
muse came online

1899
01:11:52,070 --> 01:11:48,560
sorry this wrong wrong muse

1900
01:11:54,630 --> 01:11:52,080
this actually is what you get here so

1901
01:11:56,229 --> 01:11:54,640
this was the hubble deep field again and

1902
01:11:58,630 --> 01:11:56,239
on the left you have the reconstructed

1903
01:12:01,430 --> 01:11:58,640
image of the

1904
01:12:03,189 --> 01:12:01,440
muse field of view

1905
01:12:05,990 --> 01:12:03,199
and in each of this point we get a

1906
01:12:08,709 --> 01:12:06,000
spectrum if the conditions are right not

1907
01:12:10,149 --> 01:12:08,719
always within the spectrum and

1908
01:12:11,830 --> 01:12:10,159
so this is the distribution of the

1909
01:12:13,590 --> 01:12:11,840
spectra that we got

1910
01:12:15,669 --> 01:12:13,600
and interestingly

1911
01:12:18,630 --> 01:12:15,679
i mean quite amazingly that

1912
01:12:21,110 --> 01:12:18,640
with just 100 hours of observation

1913
01:12:24,149 --> 01:12:21,120

we get something like 1300 wet shift

1914
01:12:25,510 --> 01:12:24,159
here this was 10 times more than all the

1915
01:12:27,430 --> 01:12:25,520
rat shield that were obtained in the

1916
01:12:29,350 --> 01:12:27,440
previous 10 years

1917
01:12:32,630 --> 01:12:29,360
since the hubble space telescope

1918
01:12:34,870 --> 01:12:32,640
observed this particular field

1919
01:12:36,950 --> 01:12:34,880
again diabolo spectacle was not just a

1920
01:12:39,270 --> 01:12:36,960
particular addition here it was key

1921
01:12:41,189 --> 01:12:39,280
because in in extracting the sources

1922
01:12:42,470 --> 01:12:41,199
here

1923
01:12:43,910 --> 01:12:42,480
we used

1924
01:12:46,630 --> 01:12:43,920
as priors

1925
01:12:48,790 --> 01:12:46,640
the precise location of where the hubble

1926
01:12:51,590 --> 01:12:48,800
space telescope images

1927
01:12:54,870 --> 01:12:51,600
tell us where the galaxies were

1928
01:12:57,669 --> 01:12:54,880
but sometimes we can also find

1929
01:12:59,669 --> 01:12:57,679
objects that were not identified

1930
01:13:01,750 --> 01:12:59,679
by the hubble images because in

1931
01:13:04,470 --> 01:13:01,760
particular they had properties that were

1932
01:13:08,470 --> 01:13:04,480
not captured by the broadband filters

1933
01:13:11,430 --> 01:13:10,070
at the very

1934
01:13:14,390 --> 01:13:11,440
you know

1935
01:13:17,510 --> 01:13:14,400
close end of this hubble deep field

1936
01:13:18,630 --> 01:13:17,520
say between redshift 0 and 1 so

1937
01:13:21,770 --> 01:13:18,640
almost

1938
01:13:22,870 --> 01:13:21,780

up to the half the age of the universe

1939
01:13:24,790 --> 01:13:22,880
[Music]

1940
01:13:27,110 --> 01:13:24,800
the this music observation also

1941
01:13:29,590 --> 01:13:27,120
delivered proper maps

1942
01:13:31,590 --> 01:13:29,600
for the velocity of the stars and the

1943
01:13:33,350 --> 01:13:31,600
gas so what you see here is the muse

1944
01:13:36,070 --> 01:13:33,360
wide light images of these very distant

1945
01:13:37,750 --> 01:13:36,080
galaxies the hst image

1946
01:13:39,750 --> 01:13:37,760
and then here you have the velocity and

1947
01:13:43,189 --> 01:13:39,760
velocity field of the stars

1948
01:13:45,510 --> 01:13:43,199
using the hst images you can construct

1949
01:13:47,270 --> 01:13:45,520
dynamical models to actually interpret

1950
01:13:48,630 --> 01:13:47,280
the velocity fields and the result

1951
01:13:49,990 --> 01:13:48,640
actually is that

1952
01:13:52,229 --> 01:13:50,000
by the time

1953
01:13:53,270 --> 01:13:52,239
that we reach around four to seven giga

1954
01:13:54,550 --> 01:13:53,280
years ago

1955
01:13:56,550 --> 01:13:54,560
it seems that

1956
01:13:58,709 --> 01:13:56,560
regular satellite disks were already in

1957
01:14:00,709 --> 01:13:58,719
place in the universe

1958
01:14:02,149 --> 01:14:00,719
which is kind of interesting

1959
01:14:03,669 --> 01:14:02,159
if not amazing

1960
01:14:05,110 --> 01:14:03,679
if you think about it

1961
01:14:07,189 --> 01:14:05,120
um

1962
01:14:09,750 --> 01:14:07,199
but that was not the case and this is

1963
01:14:11,669 --> 01:14:09,760

leading now to my conclusions for very

1964
01:14:14,550 --> 01:14:11,679
distant galaxies so when we jump to

1965
01:14:17,030 --> 01:14:14,560
retro one to achieve two

1966
01:14:18,630 --> 01:14:17,040
well you see that even

1967
01:14:21,030 --> 01:14:18,640
and we do this

1968
01:14:23,669 --> 01:14:21,040
in first place this was done by natasha

1969
01:14:25,910 --> 01:14:23,679
fosher schreiber in 2009 using a

1970
01:14:27,830 --> 01:14:25,920
symphony

1971
01:14:29,510 --> 01:14:27,840
near infant spectrograph

1972
01:14:32,950 --> 01:14:29,520
always at the vlt

1973
01:14:34,229 --> 01:14:32,960
um here also you find that

1974
01:14:36,229 --> 01:14:34,239
you know even when they are regularly

1975
01:14:38,790 --> 01:14:36,239
rotating galaxies are very turbulent

1976
01:14:42,070 --> 01:14:38,800
disks so we are for we are looking at

1977
01:14:44,550 --> 01:14:42,080
star forming galaxies but it's not clear

1978
01:14:46,229 --> 01:14:44,560
you know what they look like and even

1979
01:14:47,350 --> 01:14:46,239
when they are regularly rotating they

1980
01:14:49,750 --> 01:14:47,360
really have

1981
01:14:52,630 --> 01:14:49,760
discs that are clumpy and they have

1982
01:14:54,550 --> 01:14:52,640
really strong uh turbulence in them so

1983
01:14:57,350 --> 01:14:54,560
they are not quite like the discs that

1984
01:14:58,950 --> 01:14:57,360
we observed today or even that we

1985
01:15:00,310 --> 01:14:58,960
observe

1986
01:15:02,149 --> 01:15:00,320
you know by

1987
01:15:03,990 --> 01:15:02,159
four to seven giga years ago so here

1988
01:15:05,510 --> 01:15:04,000

we're talking three giga years after the

1989
01:15:06,950 --> 01:15:05,520
big bang

1990
01:15:08,709 --> 01:15:06,960
um

1991
01:15:10,709 --> 01:15:08,719
and so lastly

1992
01:15:13,430 --> 01:15:10,719
to really assess whether these were

1993
01:15:17,270 --> 01:15:13,440
discs or not a more recent study that

1994
01:15:19,030 --> 01:15:17,280
used hst is the one by sergio takala i

1995
01:15:21,350 --> 01:15:19,040
want to mention just because it's it's

1996
01:15:23,189 --> 01:15:21,360
the last connection between hubble

1997
01:15:25,590 --> 01:15:23,199
and and

1998
01:15:28,229 --> 01:15:25,600
on this very an integral spectroscopy in

1999
01:15:29,669 --> 01:15:28,239
these very distant galaxies as an

2000
01:15:32,310 --> 01:15:29,679
example

2001
01:15:34,390 --> 01:15:32,320
here you have the images from humble

2002
01:15:36,470 --> 01:15:34,400
they are not super great images but

2003
01:15:39,270 --> 01:15:36,480
that's the best that we can get

2004
01:15:40,229 --> 01:15:39,280
and still the analysis here of the how

2005
01:15:41,990 --> 01:15:40,239
the light

2006
01:15:44,709 --> 01:15:42,000
was distributed as a function from the

2007
01:15:47,910 --> 01:15:44,719
center tells us that these galaxies they

2008
01:15:48,870 --> 01:15:47,920
really are disks uh for the most part

2009
01:15:52,229 --> 01:15:48,880
um

2010
01:15:54,310 --> 01:15:52,239
but they are not like the disks today

2011
01:15:56,229 --> 01:15:54,320
this brings on to the con conclusion

2012
01:15:58,470 --> 01:15:56,239
that you know especially if we want to

2013
01:16:02,870 --> 01:15:58,480

explore galaxies in this regime we now

2014
01:16:05,030 --> 01:16:02,880
need jwst and fortunately jwst

2015
01:16:07,830 --> 01:16:05,040
finally has an integral field

2016
01:16:10,229 --> 01:16:07,840
spectrograph so we are past this regime

2017
01:16:11,270 --> 01:16:10,239
where we had to use hubble for great

2018
01:16:12,709 --> 01:16:11,280
detail

2019
01:16:15,270 --> 01:16:12,719
imaging and

2020
01:16:16,950 --> 01:16:15,280
uh ground-based integral spectrograph on

2021
01:16:19,350 --> 01:16:16,960
the ground to really get spectra

2022
01:16:20,709 --> 01:16:19,360
everywhere and understand and combine

2023
01:16:21,910 --> 01:16:20,719
the two

2024
01:16:25,110 --> 01:16:21,920
now

2025
01:16:26,790 --> 01:16:25,120
jwst has an interview for spectrograph

2026
01:16:28,790 --> 01:16:26,800
so you can do this

2027
01:16:31,430 --> 01:16:28,800
things admittedly the field of view is

2028
01:16:34,630 --> 01:16:31,440
very small but then again very far away

2029
01:16:36,229 --> 01:16:34,640
galaxies are also very tiny so i'm here

2030
01:16:38,950 --> 01:16:36,239
i will basically stop

2031
01:16:40,070 --> 01:16:38,960
thank you very much

2032
01:16:42,550 --> 01:16:40,080
all right

2033
01:16:44,470 --> 01:16:42,560
thank you very much mark

2034
01:16:46,229 --> 01:16:44,480
that was

2035
01:16:47,830 --> 01:16:46,239
an incredible

2036
01:16:50,149 --> 01:16:47,840
amount of information not only just

2037
01:16:51,990 --> 01:16:50,159
about getting into the basic spectra and

2038
01:16:54,550 --> 01:16:52,000

long-slit spectroscopy and then working

2039
01:16:57,830 --> 01:16:54,560
the interval field spectroscopy but then

2040
01:16:58,790 --> 01:16:57,840
all these various uses of ifs um across

2041
01:17:02,790 --> 01:16:58,800
the

2042
01:17:05,189 --> 01:17:02,800
astronomy um

2043
01:17:08,149 --> 01:17:05,199
so one things i wanted to ask to make

2044
01:17:10,790 --> 01:17:08,159
clear for our audience is the um pixel

2045
01:17:12,229 --> 01:17:10,800
resolution okay so when we take an image

2046
01:17:13,030 --> 01:17:12,239
with hubble we're used to having you

2047
01:17:14,630 --> 01:17:13,040
know

2048
01:17:17,350 --> 01:17:14,640
tens of millions of pixels right we got

2049
01:17:19,030 --> 01:17:17,360
a 4k detector so 16 million pixels per

2050
01:17:21,910 --> 01:17:19,040
image right

2051
01:17:23,350 --> 01:17:21,920
um and muse if we think of that as the

2052
01:17:25,750 --> 01:17:23,360
the standard uh

2053
01:17:26,709 --> 01:17:25,760
which is sort of the you know definitely

2054
01:17:34,550 --> 01:17:26,719
the

2055
01:17:38,310 --> 01:17:34,560
somebody asked online which is a really

2056
01:17:40,310 --> 01:17:38,320
cool question was what is its wavelength

2057
01:17:43,270 --> 01:17:40,320
spacing as well how many nanometers

2058
01:17:44,630 --> 01:17:43,280
between different

2059
01:17:46,149 --> 01:17:44,640
pixels in the spectra if you want to

2060
01:17:48,070 --> 01:17:46,159
think of that so you've got this data

2061
01:17:49,830 --> 01:17:48,080
cube and your images

2062
01:17:51,350 --> 01:17:49,840
and then you got the images stretched

2063
01:17:53,510 --> 01:17:51,360

out over wavelength what's our

2064
01:17:55,030 --> 01:17:53,520
resolution of this data cube

2065
01:17:56,709 --> 01:17:55,040
okay so

2066
01:17:58,550 --> 01:17:56,719
yeah thanks for the question because

2067
01:18:01,990 --> 01:17:58,560
this is the kind of data that i didn't

2068
01:18:04,229 --> 01:18:02,000
want to delve into um but so as you say

2069
01:18:05,270 --> 01:18:04,239
we are talking about a tenth of an arc

2070
01:18:06,790 --> 01:18:05,280
second

2071
01:18:08,790 --> 01:18:06,800
uh for hubble

2072
01:18:11,910 --> 01:18:08,800
okay which

2073
01:18:14,149 --> 01:18:11,920
brings you to say 10 parsec at 20

2074
01:18:16,310 --> 01:18:14,159
megapass x or the nearby

2075
01:18:19,270 --> 01:18:16,320
clusters of galaxies with hubble you can

2076
01:18:21,830 --> 01:18:19,280
resolve 10 parsecs if you want

2077
01:18:25,030 --> 01:18:21,840
and with muse we are

2078
01:18:26,870 --> 01:18:25,040
we actually have a good sampling of 0.2

2079
01:18:28,950 --> 01:18:26,880
arc second per

2080
01:18:30,870 --> 01:18:28,960
pixel which in the case of integer

2081
01:18:31,990 --> 01:18:30,880
spectroscopy is called spark cells

2082
01:18:33,750 --> 01:18:32,000
because

2083
01:18:36,709 --> 01:18:33,760
it looks like a pixel but in reality it

2084
01:18:38,470 --> 01:18:36,719
does have a spectrum all the way through

2085
01:18:44,149 --> 01:18:38,480
so

2086
01:18:46,630 --> 01:18:44,159
we can sample very well the psf in

2087
01:18:48,950 --> 01:18:46,640
reality we are limited by ground-based

2088
01:18:51,830 --> 01:18:48,960

scenes so sometimes if we are lucky

2089
01:18:54,070 --> 01:18:51,840
we go less than a second so especially

2090
01:18:56,550 --> 01:18:54,080
at vlt on paranal you typically have

2091
01:18:58,390 --> 01:18:56,560
point eight exactly no resolution

2092
01:19:00,709 --> 01:18:58,400
so it's still it's still a good ten

2093
01:19:02,790 --> 01:19:00,719
times less than nine apple

2094
01:19:05,110 --> 01:19:02,800
and then in terms of wavelength range it

2095
01:19:07,350 --> 01:19:05,120
goes from four thousand to

2096
01:19:09,030 --> 01:19:07,360
nine thousand essentially well you know

2097
01:19:10,630 --> 01:19:09,040
four thousand and five hundred to a bit

2098
01:19:13,430 --> 01:19:10,640
more than nine thousand

2099
01:19:16,470 --> 01:19:13,440
which allows you to essentially cover

2100
01:19:18,630 --> 01:19:16,480
typical optical spectrum where you have

2101
01:19:21,270 --> 01:19:18,640
the metal lines where you have the

2102
01:19:23,750 --> 01:19:21,280
balmer lines for recombination lines

2103
01:19:28,149 --> 01:19:23,760
from star forming region you can cover

2104
01:19:29,750 --> 01:19:28,159
also oxygen free and other very strong

2105
01:19:31,270 --> 01:19:29,760
forbidden lines from

2106
01:19:34,390 --> 01:19:31,280
other kind of excitation such as black

2107
01:19:36,310 --> 01:19:34,400
hole accretion and then in the far right

2108
01:19:39,030 --> 01:19:36,320
in the on the red end you have the

2109
01:19:43,430 --> 01:19:39,040
calcium triplet which is very important

2110
01:19:46,149 --> 01:19:44,870
and yeah that's a good that's a good

2111
01:19:48,229 --> 01:19:46,159
range also to

2112
01:19:50,390 --> 01:19:48,239
to also touch on another aspect that i

2113
01:19:53,189 --> 01:19:50,400

didn't touch which is the reddening so

2114
01:19:54,229 --> 01:19:53,199
with spectroscopy we can talk about

2115
01:19:56,550 --> 01:19:54,239
gas

2116
01:19:57,590 --> 01:19:56,560
and stars but we can also talk about

2117
01:19:59,510 --> 01:19:57,600
dust

2118
01:20:00,790 --> 01:19:59,520
that absorb the light more efficiently

2119
01:20:03,669 --> 01:20:00,800
in the blue and the red so we can

2120
01:20:05,669 --> 01:20:03,679
actually appreciate how much

2121
01:20:06,870 --> 01:20:05,679
galaxy spectrum is red and or not by

2122
01:20:10,470 --> 01:20:06,880
dust

2123
01:20:13,110 --> 01:20:10,480
okay so i guess the but one one point of

2124
01:20:15,750 --> 01:20:13,120
the um the viewer's question was how

2125
01:20:18,390 --> 01:20:15,760
many of these layers uh in spectra do

2126
01:20:20,390 --> 01:20:18,400
you have oh between 4 000 and 9 000 is

2127
01:20:22,790 --> 01:20:20,400
there you know is it

2128
01:20:26,709 --> 01:20:22,800
every 10 nanometers or 20 nanometers or

2129
01:20:30,070 --> 01:20:26,719
whatever it goes every 1.2 um

2130
01:20:35,189 --> 01:20:32,189
but essentially you have essentially

2131
01:20:36,950 --> 01:20:35,199
3600 individual emails that's the number

2132
01:20:39,990 --> 01:20:36,960
i think they were looking for 3600

2133
01:20:42,229 --> 01:20:40,000
layers so you're taking 3600 images

2134
01:20:43,510 --> 01:20:42,239
basically with every observation you do

2135
01:20:45,830 --> 01:20:43,520
with muse here

2136
01:20:47,910 --> 01:20:45,840
yeah that's cool isn't that i just

2137
01:20:50,070 --> 01:20:47,920
thought that's a lot of fun

2138
01:20:52,790 --> 01:20:50,080

all right so we've had a good chat here

2139
01:20:54,310 --> 01:20:52,800
um on on the youtube and grant justice

2140
01:20:56,629 --> 01:20:54,320
has been monitoring it a little bit more

2141
01:20:59,270 --> 01:20:56,639
closely than i have so grant would you

2142
01:21:01,110 --> 01:20:59,280
like to turn on your video

2143
01:21:03,270 --> 01:21:01,120
and bring up some of the questions you

2144
01:21:05,430 --> 01:21:03,280
saw in the chat

2145
01:21:06,550 --> 01:21:05,440
absolutely

2146
01:21:09,350 --> 01:21:06,560
all right

2147
01:21:11,270 --> 01:21:09,360
so first up you got my first question i

2148
01:21:12,950 --> 01:21:11,280
was going to ask it too i loved that one

2149
01:21:14,629 --> 01:21:12,960
that's a really good one

2150
01:21:17,110 --> 01:21:14,639
secondly um

2151
01:21:18,229 --> 01:21:17,120
kind of continuing on with our theme of

2152
01:21:20,310 --> 01:21:18,239
like

2153
01:21:22,310 --> 01:21:20,320
muse and for anyone that needs a

2154
01:21:24,470 --> 01:21:22,320
reminder of that it's multi-unit

2155
01:21:27,189 --> 01:21:24,480
spectroscopic explorer

2156
01:21:30,149 --> 01:21:27,199
i get lost in the acronyms as well

2157
01:21:31,750 --> 01:21:30,159
but what would be the difference between

2158
01:21:38,870 --> 01:21:31,760
a muse

2159
01:21:39,910 --> 01:21:38,880
he was saying something unlike for

2160
01:21:43,110 --> 01:21:39,920
instance

2161
01:21:45,110 --> 01:21:43,120
the moon something that would be outside

2162
01:21:48,310 --> 01:21:45,120
of the normal

2163
01:21:50,229 --> 01:21:48,320

range of interference but

2164
01:21:52,550 --> 01:21:50,239
maybe half of the year wouldn't be

2165
01:21:54,310 --> 01:21:52,560
functional

2166
01:21:57,270 --> 01:21:54,320
how would that affect your data your

2167
01:21:58,070 --> 01:21:57,280
observations if you had something

2168
01:22:00,390 --> 01:21:58,080
well

2169
01:22:02,229 --> 01:22:00,400
for sure if we were on the moon that's a

2170
01:22:03,590 --> 01:22:02,239
good interesting let's let's let's let's

2171
01:22:06,310 --> 01:22:03,600
talk about

2172
01:22:08,310 --> 01:22:06,320
let me get let give me the moon okay so

2173
01:22:10,310 --> 01:22:08,320
the online loves the moon is all yours

2174
01:22:11,030 --> 01:22:10,320
okay

2175
01:22:12,390 --> 01:22:11,040
so

2176
01:22:15,030 --> 01:22:12,400
various things first i don't have an

2177
01:22:17,270 --> 01:22:15,040
atmosphere to deal with and it's true

2178
01:22:19,189 --> 01:22:17,280
that muse also works with adaptive

2179
01:22:21,830 --> 01:22:19,199
optics so we can do the same trick you

2180
01:22:24,149 --> 01:22:21,840
know in fact we don't we can you know we

2181
01:22:26,790 --> 01:22:24,159
can make the resolution better but it

2182
01:22:29,709 --> 01:22:26,800
still goes from let's say 0.8 which is

2183
01:22:33,350 --> 01:22:29,719
the best natural scene to perhaps

2184
01:22:35,750 --> 01:22:33,360
0.4.3 so it's it's like correction for

2185
01:22:36,709 --> 01:22:35,760
super duper natural imaging rather than

2186
01:22:39,189 --> 01:22:36,719
bringing it

2187
01:22:42,070 --> 01:22:39,199
back to what i could do with with with

2188
01:22:45,590 --> 01:22:42,080

hubble uh so it's good but it's not

2189
01:22:46,629 --> 01:22:45,600
super uh so of course in space or in on

2190
01:22:49,030 --> 01:22:46,639
the moon

2191
01:22:50,629 --> 01:22:49,040
i would basically have like hubble okay

2192
01:22:52,229 --> 01:22:50,639
no problem with that

2193
01:22:53,910 --> 01:22:52,239
and also another thing that i could do

2194
01:22:56,870 --> 01:22:53,920
if i were in space

2195
01:22:59,669 --> 01:22:56,880
is that i could build a muse

2196
01:23:01,990 --> 01:22:59,679
that probes also the other wavelengths

2197
01:23:03,990 --> 01:23:02,000
that we have no access because of the

2198
01:23:06,149 --> 01:23:04,000
screen of the atmosphere so for instance

2199
01:23:07,750 --> 01:23:06,159
i could have a

2200
01:23:10,310 --> 01:23:07,760
uv muse

2201
01:23:12,629 --> 01:23:10,320
i could look at the uv lines and

2202
01:23:13,280 --> 01:23:12,639
um and so that will be actually quite

2203
01:23:14,550 --> 01:23:13,290
good um

2204
01:23:17,350 --> 01:23:14,560
[Music]

2205
01:23:19,350 --> 01:23:17,360
there are plans to make a blue muse now

2206
01:23:21,030 --> 01:23:19,360
but blue means you know just down to

2207
01:23:22,550 --> 01:23:21,040
probably three thousand extra not much

2208
01:23:24,470 --> 01:23:22,560
more so

2209
01:23:26,709 --> 01:23:24,480
i just love that name and everything

2210
01:23:27,990 --> 01:23:26,719
about it blue muse is

2211
01:23:30,229 --> 01:23:28,000
phenomenal

2212
01:23:32,229 --> 01:23:30,239
and um you know it's important that we

2213
01:23:33,910 --> 01:23:32,239

make the observation that as

2214
01:23:36,229 --> 01:23:33,920
you've done that adaptive optics is

2215
01:23:38,709 --> 01:23:36,239
great um and in certain cases they can

2216
01:23:41,030 --> 01:23:38,719
almost get hubble hubble resolution

2217
01:23:42,870 --> 01:23:41,040
but generally it works more best at

2218
01:23:46,310 --> 01:23:42,880
infrared um and it only works over a

2219
01:23:51,830 --> 01:23:49,110
that's an important question frank sorry

2220
01:23:53,189 --> 01:23:51,840
uh is is indeed this is a correction in

2221
01:23:55,270 --> 01:23:53,199
the optical

2222
01:23:57,110 --> 01:23:55,280
uh i at the end of the talk i mentioned

2223
01:23:59,669 --> 01:23:57,120
this symphony data

2224
01:24:02,310 --> 01:23:59,679
um that indeed give gave a great

2225
01:24:04,470 --> 01:24:02,320
resolution in the infrared so in the in

2226
01:24:05,669 --> 01:24:04,480
dear infrared you actually go

2227
01:24:07,990 --> 01:24:05,679
almost

2228
01:24:10,629 --> 01:24:08,000
as good as uh

2229
01:24:13,189 --> 01:24:10,639
as above but not as good as james webb

2230
01:24:14,790 --> 01:24:13,199
yet right well and james webb of course

2231
01:24:16,629 --> 01:24:14,800
isn't quite as i showed isn't quite

2232
01:24:18,790 --> 01:24:16,639
aligned yet but when james webb gets

2233
01:24:20,629 --> 01:24:18,800
going uh does the comparison will then

2234
01:24:23,110 --> 01:24:20,639
be oh can we get as good as james webb

2235
01:24:28,070 --> 01:24:25,430
all right grant what's the next question

2236
01:24:30,629 --> 01:24:28,080
sure um it just that's a rotating theme

2237
01:24:32,550 --> 01:24:30,639
like getting away from interference from

2238
01:24:34,390 --> 01:24:32,560

earth other sorts of things

2239
01:24:37,189 --> 01:24:34,400
um oh

2240
01:24:40,310 --> 01:24:37,199
this is more for you frank

2241
01:24:42,550 --> 01:24:40,320
any plans for a deep field again

2242
01:24:43,590 --> 01:24:42,560
from hubble before we end life

2243
01:24:45,189 --> 01:24:43,600
um

2244
01:24:47,510 --> 01:24:45,199
as far as i know no

2245
01:24:50,550 --> 01:24:47,520
um we have done the hubble ultra deep

2246
01:24:54,070 --> 01:24:50,560
field four times um getting successfully

2247
01:24:56,709 --> 01:24:54,080
deeper and deeper in that area um i do

2248
01:25:01,030 --> 01:24:56,719
not have the

2249
01:25:02,709 --> 01:25:01,040
james webb in front of me but i really

2250
01:25:05,270 --> 01:25:02,719
feel like one of the early observations

2251
01:25:06,709 --> 01:25:05,280
is going to be a web deep field okay and

2252
01:25:08,390 --> 01:25:06,719
that's where we're really going to have

2253
01:25:11,430 --> 01:25:08,400
um new science coming up is the

2254
01:25:13,910 --> 01:25:11,440
comparison between the hubble deep field

2255
01:25:15,350 --> 01:25:13,920
and the web deep field so we can look

2256
01:25:17,830 --> 01:25:15,360
forward to that

2257
01:25:19,830 --> 01:25:17,840
probably in the next year or so

2258
01:25:21,669 --> 01:25:19,840
sometime sometime

2259
01:25:23,990 --> 01:25:21,679
we'll see

2260
01:25:26,629 --> 01:25:24,000
all right um this was going back to some

2261
01:25:28,709 --> 01:25:26,639
of when you were explaining about the

2262
01:25:31,110 --> 01:25:28,719
the charts and

2263
01:25:33,270 --> 01:25:31,120

all of our various axes of different

2264
01:25:35,750 --> 01:25:33,280
information um when you're working with

2265
01:25:37,750 --> 01:25:35,760
the globular clusters

2266
01:25:40,229 --> 01:25:37,760
what's the average size like how many

2267
01:25:42,229 --> 01:25:40,239
stars are in an average globular cluster

2268
01:25:44,790 --> 01:25:42,239
that you were observing

2269
01:25:47,030 --> 01:25:44,800
so a globular cluster from now wrong

2270
01:25:48,629 --> 01:25:47,040
packs up at most you know 10 to the 6

2271
01:25:53,510 --> 01:25:48,639
million stars

2272
01:25:55,990 --> 01:25:53,520
compacted

2273
01:25:57,830 --> 01:25:56,000
i think the half-life radius of of

2274
01:25:59,350 --> 01:25:57,840
globular cluster is typically around

2275
01:26:01,669 --> 01:25:59,360
five parsec

2276
01:26:03,590 --> 01:26:01,679
so globular clusters are really really

2277
01:26:04,870 --> 01:26:03,600
dense i mean there's all sorts of funny

2278
01:26:06,870 --> 01:26:04,880
things that actually happens in the

2279
01:26:08,550 --> 01:26:06,880
center of global cluster between stars

2280
01:26:10,790 --> 01:26:08,560
where actually stars do actually meet

2281
01:26:12,950 --> 01:26:10,800
each other unlike you know

2282
01:26:15,270 --> 01:26:12,960
in our solar neighborhood where

2283
01:26:16,310 --> 01:26:15,280
stars are very far away from each other

2284
01:26:19,830 --> 01:26:16,320
um

2285
01:26:21,110 --> 01:26:19,840
so that's our compact it is and

2286
01:26:22,950 --> 01:26:21,120
and yes

2287
01:26:26,950 --> 01:26:22,960
this this is the

2288
01:26:29,590 --> 01:26:26,960

this actually also helps in in that

2289
01:26:31,270 --> 01:26:29,600
yes we identify them with with hubble

2290
01:26:33,510 --> 01:26:31,280
but it also makes it easier to actually

2291
01:26:36,229 --> 01:26:33,520
extract spectra because even if with

2292
01:26:37,030 --> 01:26:36,239
muse even if we don't really resolve

2293
01:26:39,750 --> 01:26:37,040
them

2294
01:26:41,430 --> 01:26:39,760
um we know it's badly a point source and

2295
01:26:43,430 --> 01:26:41,440
then there is the galaxy background for

2296
01:26:45,990 --> 01:26:43,440
the rest of the galaxy so we essentially

2297
01:26:48,149 --> 01:26:46,000
can just take the spectrum of the galaxy

2298
01:26:50,149 --> 01:26:48,159
background and subtract it away and we

2299
01:26:52,390 --> 01:26:50,159
are left with most of the central region

2300
01:26:54,310 --> 01:26:52,400
where is dominated by the globular

2301
01:26:55,990 --> 01:26:54,320
cluster light

2302
01:26:57,430 --> 01:26:56,000
yeah i would comment on the density of

2303
01:27:00,629 --> 01:26:57,440
globular clusters i once did a

2304
01:27:01,750 --> 01:27:00,639
visualization of if our sun were located

2305
01:27:04,070 --> 01:27:01,760
inside

2306
01:27:05,430 --> 01:27:04,080
a globular cluster and basically we

2307
01:27:07,830 --> 01:27:05,440
astronomers would be out of business

2308
01:27:09,669 --> 01:27:07,840
except for stellar astronomy okay

2309
01:27:11,669 --> 01:27:09,679
because the whole sky would be covered

2310
01:27:13,110 --> 01:27:11,679
with all this or radio astronomy or

2311
01:27:16,310 --> 01:27:13,120
something because the whole sky would be

2312
01:27:17,830 --> 01:27:16,320
covered with very bright stars and to be

2313
01:27:20,470 --> 01:27:17,840

we wouldn't see other galaxies very

2314
01:27:24,790 --> 01:27:22,790
talking about interference

2315
01:27:27,590 --> 01:27:24,800
what's next

2316
01:27:30,550 --> 01:27:27,600
all right um oh here's a good one

2317
01:27:32,709 --> 01:27:30,560
uh is it possible to combine ifs with

2318
01:27:35,510 --> 01:27:32,719
radio interferometry

2319
01:27:36,950 --> 01:27:35,520
and how is it that we'll see the spectra

2320
01:27:39,750 --> 01:27:36,960
of infrared

2321
01:27:41,350 --> 01:27:39,760
or better yet yeah how do we combine ifs

2322
01:27:42,950 --> 01:27:41,360
with radio interferometry that's a good

2323
01:27:46,550 --> 01:27:42,960
question

2324
01:27:49,350 --> 01:27:46,560
well okay so there's many many well

2325
01:27:51,270 --> 01:27:49,360
we don't combine it directly but we

2326
01:27:52,950 --> 01:27:51,280
combine the information

2327
01:27:55,350 --> 01:27:52,960
and in fact actually one thing i forgot

2328
01:27:56,910 --> 01:27:55,360
to mention in my talk is that i don't

2329
01:27:59,750 --> 01:27:56,920
want to claim actually that interview

2330
01:28:02,310 --> 01:27:59,760
philosophy is the first

2331
01:28:05,110 --> 01:28:02,320
first time that we are able to take

2332
01:28:06,709 --> 01:28:05,120
spectra everywhere in a in in a in a

2333
01:28:09,270 --> 01:28:06,719
field of view or in the fuse region

2334
01:28:10,950 --> 01:28:09,280
because in fact radio interferometry

2335
01:28:12,149 --> 01:28:10,960
radio astronomy has been doing for this

2336
01:28:13,590 --> 01:28:12,159
for for

2337
01:28:15,189 --> 01:28:13,600
a long time

2338
01:28:17,590 --> 01:28:15,199

you know the first rotation curves of

2339
01:28:20,709 --> 01:28:17,600
galaxies were in fact worked out with

2340
01:28:22,310 --> 01:28:20,719
radio astronomy and in this case they

2341
01:28:23,430 --> 01:28:22,320
just follow one particular line from

2342
01:28:27,030 --> 01:28:23,440
hydrogen

2343
01:28:29,990 --> 01:28:27,040
um and likewise when you go into chandra

2344
01:28:31,910 --> 01:28:30,000
or x-ray astronomy so there you have

2345
01:28:34,709 --> 01:28:31,920
each little photon when it comes to the

2346
01:28:36,149 --> 01:28:34,719
receptor we actually tell his energy so

2347
01:28:38,390 --> 01:28:36,159
and essentially we know the energy of

2348
01:28:40,709 --> 01:28:38,400
each little photon so at every place we

2349
01:28:43,590 --> 01:28:40,719
actually have a small spectrum of just

2350
01:28:45,750 --> 01:28:43,600
maybe 10 or photons or so

2351
01:28:48,390 --> 01:28:45,760
but still we have we have a spectrum

2352
01:28:49,990 --> 01:28:48,400
everywhere so a good a good example of

2353
01:28:53,510 --> 01:28:50,000
how you combine

2354
01:28:59,030 --> 01:28:55,110
from

2355
01:29:00,390 --> 01:28:59,040
spectroscopy is maybe in a better

2356
01:29:02,629 --> 01:29:00,400
understanding

2357
01:29:03,510 --> 01:29:02,639
the the accretion

2358
01:29:04,790 --> 01:29:03,520
and

2359
01:29:06,390 --> 01:29:04,800
of gas

2360
01:29:08,790 --> 01:29:06,400
so you

2361
01:29:11,430 --> 01:29:08,800
can you know with interferometry or you

2362
01:29:13,110 --> 01:29:11,440
know you can see the gas the neutral gas

2363
01:29:15,110 --> 01:29:13,120

coming to the galaxy

2364
01:29:17,110 --> 01:29:15,120
and then as it goes to in the center of

2365
01:29:19,030 --> 01:29:17,120
the galaxy it becomes ionized because

2366
01:29:20,229 --> 01:29:19,040
there are now stars that start to ionize

2367
01:29:23,110 --> 01:29:20,239
the gas

2368
01:29:24,550 --> 01:29:23,120
um and then later on you can see with

2369
01:29:26,790 --> 01:29:24,560
the nut if you actually go into the

2370
01:29:28,629 --> 01:29:26,800
millimeter what you see

2371
01:29:31,110 --> 01:29:28,639
on the other hand is not the neutral gas

2372
01:29:33,110 --> 01:29:31,120
but you see the molecular gas which is

2373
01:29:34,950 --> 01:29:33,120
uh the part of the gas cloud they're

2374
01:29:37,189 --> 01:29:34,960
very very cold and in the center or

2375
01:29:39,510 --> 01:29:37,199
first in in in orion only in the very

2376
01:29:40,310 --> 01:29:39,520
central region you have molecular gas

2377
01:29:44,550 --> 01:29:40,320
and

2378
01:29:46,070 --> 01:29:44,560
next you form stars

2379
01:29:49,590 --> 01:29:46,080
so you can see

2380
01:29:52,629 --> 01:29:49,600
the i the neutral gas then the ionized

2381
01:29:54,310 --> 01:29:52,639
gas and then in amongst this ionized gas

2382
01:29:56,790 --> 01:29:54,320
maybe in the spiral arms or maybe with

2383
01:29:59,270 --> 01:29:56,800
the center you actually find the very

2384
01:30:01,430 --> 01:29:59,280
cold molecular gas and you know the

2385
01:30:03,430 --> 01:30:01,440
molecular gas and the neutral gas you

2386
01:30:05,830 --> 01:30:03,440
get it with interferometry from radio

2387
01:30:09,110 --> 01:30:05,840
and millimeter observations

2388
01:30:10,790 --> 01:30:09,120

right i hope this is so fascinating

2389
01:30:12,709 --> 01:30:10,800
well i mean it's it it's something that

2390
01:30:15,189 --> 01:30:12,719
we astronomers sort of take for for

2391
01:30:17,189 --> 01:30:15,199
granted that we have these different uh

2392
01:30:19,910 --> 01:30:17,199
variants in the interstellar medium but

2393
01:30:21,830 --> 01:30:19,920
you know showing how we we get the the

2394
01:30:23,910 --> 01:30:21,840
observations that identify the different

2395
01:30:26,149 --> 01:30:23,920
pieces of the interstellar medium is uh

2396
01:30:26,950 --> 01:30:26,159
you know there's an awful lot of work to

2397
01:30:29,030 --> 01:30:26,960
it

2398
01:30:31,270 --> 01:30:29,040
so um i wanted to ask a question that

2399
01:30:33,030 --> 01:30:31,280
combines two of your results okay

2400
01:30:34,390 --> 01:30:33,040
because um when you're talking about

2401
01:30:36,870 --> 01:30:34,400
star formation and you were doing the

2402
01:30:38,950 --> 01:30:36,880
plots of the the older stars versus the

2403
01:30:40,950 --> 01:30:38,960
younger stars and the younger stars were

2404
01:30:43,510 --> 01:30:40,960
in the disc and then the older stars you

2405
01:30:45,030 --> 01:30:43,520
got to about 10 to 14 giga years ago and

2406
01:30:47,110 --> 01:30:45,040
they filled out the bulge and everything

2407
01:30:49,750 --> 01:30:47,120
right so that sort of says all right the

2408
01:30:51,350 --> 01:30:49,760
disc forms you know about 10 million

2409
01:30:52,950 --> 01:30:51,360
10 giga years ago

2410
01:30:55,030 --> 01:30:52,960
um and then

2411
01:30:57,110 --> 01:30:55,040
you came up with a muse

2412
01:30:59,430 --> 01:30:57,120
of thing result where you're looking out

2413
01:31:01,990 --> 01:30:59,440

to redshift one and the discs were nice

2414
01:31:03,750 --> 01:31:02,000
smooth rotation curves four to seven

2415
01:31:05,669 --> 01:31:03,760
gigahertz so if we look at those two

2416
01:31:07,750 --> 01:31:05,679
results are we really starting getting a

2417
01:31:10,550 --> 01:31:07,760
feeling for when the discs form and when

2418
01:31:13,990 --> 01:31:10,560
they become this nice smooth um uh

2419
01:31:16,149 --> 01:31:14,000
rotation if we add those two together

2420
01:31:18,229 --> 01:31:16,159
well i i think that uh

2421
01:31:20,390 --> 01:31:18,239
the images i showed you for but that's

2422
01:31:21,910 --> 01:31:20,400
one galaxy i know different galaxies

2423
01:31:23,669 --> 01:31:21,920
right and you you have to do it in a

2424
01:31:24,950 --> 01:31:23,679
statistical sense but i was just but

2425
01:31:27,270 --> 01:31:24,960
that's an interesting galaxy because

2426
01:31:29,510 --> 01:31:27,280
that's a galaxy that actually has a very

2427
01:31:32,149 --> 01:31:29,520
nice characteristic which is that yes

2428
01:31:34,950 --> 01:31:32,159
it's especially an elliptical galaxy

2429
01:31:38,149 --> 01:31:34,960
with a flat oblate

2430
01:31:40,470 --> 01:31:38,159
main body and then a very thin disc

2431
01:31:43,270 --> 01:31:40,480
this guy is old there is no ongoing

2432
01:31:45,110 --> 01:31:43,280
stuff formation and indeed what you see

2433
01:31:46,870 --> 01:31:45,120
is that you know you have these disks

2434
01:31:49,110 --> 01:31:46,880
this this plot i showed you they started

2435
01:31:51,030 --> 01:31:49,120
for at three four five giga years and

2436
01:31:53,830 --> 01:31:51,040
then only at 10 giga years i think

2437
01:31:58,149 --> 01:31:53,840
broadly speaking is not too inconsistent

2438
01:32:00,229 --> 01:31:58,159

what we saw in the news data for disks

2439
01:32:02,229 --> 01:32:00,239
at redshift one so between four and

2440
01:32:03,750 --> 01:32:02,239
seven giga years ago is this that

2441
01:32:05,270 --> 01:32:03,760
already in place you have these nice

2442
01:32:08,629 --> 01:32:05,280
disks okay

2443
01:32:11,189 --> 01:32:08,639
so that tells me that by that time disks

2444
01:32:13,590 --> 01:32:11,199
were forming in a regular way

2445
01:32:16,149 --> 01:32:13,600
maybe in this galaxy this form earlier

2446
01:32:18,070 --> 01:32:16,159
but i mean this galaxy imagine that now

2447
01:32:20,149 --> 01:32:18,080
you know whatever galaxy is looking at

2448
01:32:22,790 --> 01:32:20,159
that time now you can form a disk and

2449
01:32:25,430 --> 01:32:22,800
these disks they look thin

2450
01:32:27,750 --> 01:32:25,440
they look dynamically cold they will

2451
01:32:28,790 --> 01:32:27,760
look like normal discs if you go back

2452
01:32:32,629 --> 01:32:28,800
another

2453
01:32:35,430 --> 01:32:32,639
three giga years you know and now you're

2454
01:32:37,510 --> 01:32:35,440
you know three giga years away from the

2455
01:32:39,750 --> 01:32:37,520
from the big bang and red shift ii

2456
01:32:44,149 --> 01:32:39,760
things are very different than this are

2457
01:32:46,390 --> 01:32:44,159
turbulent um they're much more disturbed

2458
01:32:48,550 --> 01:32:46,400
and so what is probably happening there

2459
01:32:50,870 --> 01:32:48,560
is that you have a lot of star formation

2460
01:32:53,110 --> 01:32:50,880
and you may end up with

2461
01:32:55,350 --> 01:32:53,120
with a bulge instead or with the fake

2462
01:32:57,270 --> 01:32:55,360
discs it i think the jewelry is still a

2463
01:32:59,910 --> 01:32:57,280

bit out and exactly you can bridge the

2464
01:33:01,990 --> 01:32:59,920
two but it's not too inconsistent i will

2465
01:33:03,430 --> 01:33:02,000
say the process

2466
01:33:05,350 --> 01:33:03,440
and that's that's what you saw also

2467
01:33:06,390 --> 01:33:05,360
there that the old stars are kind of

2468
01:33:07,669 --> 01:33:06,400
there

2469
01:33:09,590 --> 01:33:07,679
right

2470
01:33:11,350 --> 01:33:09,600
okay so grant do we have time we have

2471
01:33:14,229 --> 01:33:11,360
time for one more question uh do you

2472
01:33:15,510 --> 01:33:14,239
have a favorite one to put to pull

2473
01:33:17,750 --> 01:33:15,520
no there's been nothing more from the

2474
01:33:19,750 --> 01:33:17,760
chat you've answered everything uh

2475
01:33:20,709 --> 01:33:19,760
everyone asked about uh you you answered

2476
01:33:22,149 --> 01:33:20,719
the question that they want to know

2477
01:33:26,629 --> 01:33:22,159
about webb and the integral field

2478
01:33:28,390 --> 01:33:26,639
spectroscopy um so the the webs ifs is

2479
01:33:30,550 --> 01:33:28,400
going to be a small field of view and

2480
01:33:32,149 --> 01:33:30,560
it's not going to be a no uh that many

2481
01:33:34,149 --> 01:33:32,159
pixels i think if i remember it's like a

2482
01:33:36,550 --> 01:33:34,159
30 by 30 array

2483
01:33:37,990 --> 01:33:36,560
for the ifs on web

2484
01:33:40,470 --> 01:33:38,000
yeah what i know is that it's actually

2485
01:33:43,590 --> 01:33:40,480
quite quite small in the three by three

2486
01:33:45,510 --> 01:33:43,600
act seconds so that really allows you

2487
01:33:48,229 --> 01:33:45,520
for nearby galaxies which are more my

2488
01:33:50,070 --> 01:33:48,239

i'm a redshift point one guy you know

2489
01:33:51,510 --> 01:33:50,080
okay

2490
01:33:53,270 --> 01:33:51,520
you know

2491
01:33:58,070 --> 01:33:53,280
so

2492
01:33:59,110 --> 01:33:58,080
center of nearby galaxies um all right

2493
01:34:01,030 --> 01:33:59,120
you know

2494
01:34:03,590 --> 01:34:01,040
protoplanetary disks things like this

2495
01:34:06,070 --> 01:34:03,600
but you know this is really designed how

2496
01:34:07,669 --> 01:34:06,080
jane's periscope just went was primarily

2497
01:34:10,470 --> 01:34:07,679
designed to look back in time and the

2498
01:34:12,709 --> 01:34:10,480
you know origin of galaxies so

2499
01:34:14,470 --> 01:34:12,719
there's no problem with that you know

2500
01:34:15,830 --> 01:34:14,480
you will kill all these galaxies in so

2501
01:34:17,270 --> 01:34:15,840
that's that's why

2502
01:34:18,390 --> 01:34:17,280
and that's a really important point is

2503
01:34:20,470 --> 01:34:18,400
that you know

2504
01:34:22,310 --> 01:34:20,480
instruments are designed to address

2505
01:34:23,910 --> 01:34:22,320
certain problems and not address every

2506
01:34:25,110 --> 01:34:23,920
single problem out there right

2507
01:34:26,950 --> 01:34:25,120
especially when you're putting something

2508
01:34:29,110 --> 01:34:26,960
on a space telescope and it has to you

2509
01:34:31,430 --> 01:34:29,120
know it really has to pass the science

2510
01:34:32,950 --> 01:34:31,440
science reviews and everything for what

2511
01:34:35,669 --> 01:34:32,960
is this telescope going to do what's

2512
01:34:37,830 --> 01:34:35,679
what what problems is it going to answer

2513
01:34:40,870 --> 01:34:37,840

all right so i guess the last comment i

2514
01:34:43,270 --> 01:34:40,880
would have for you is the compliment on

2515
01:34:45,350 --> 01:34:43,280
getting the acronym sauron there so that

2516
01:34:48,070 --> 01:34:45,360
you have the all-seeing eye to for which

2517
01:34:49,669 --> 01:34:48,080
to study the universe right

2518
01:34:51,590 --> 01:34:49,679
that was the idea

2519
01:34:53,910 --> 01:34:51,600
i don't even remember what it stands for

2520
01:34:55,910 --> 01:34:53,920
but especially

2521
01:34:57,109 --> 01:34:55,920
yeah i you know it was made up

2522
01:34:57,990 --> 01:34:57,119
essentially

2523
01:34:59,750 --> 01:34:58,000
all right

2524
01:35:01,750 --> 01:34:59,760
well thank you very much mark thank you

2525
01:35:05,109 --> 01:35:01,760
much for joining us i think it's been

2526
01:35:07,590 --> 01:35:05,119
wonderful having a speaker from across

2527
01:35:09,910 --> 01:35:07,600
the ocean uh come and give our talk this

2528
01:35:14,550 --> 01:35:09,920
is so glad that you volunteered for this

2529
01:35:17,109 --> 01:35:14,560
uh next month uh april 5th 2022 neutrino

2530
01:35:19,030 --> 01:35:17,119
astronomy with ice cube

2531
01:35:21,590 --> 01:35:19,040
you gotta come you gotta gotta hear

2532
01:35:24,229 --> 01:35:21,600
about how we do astronomy using these