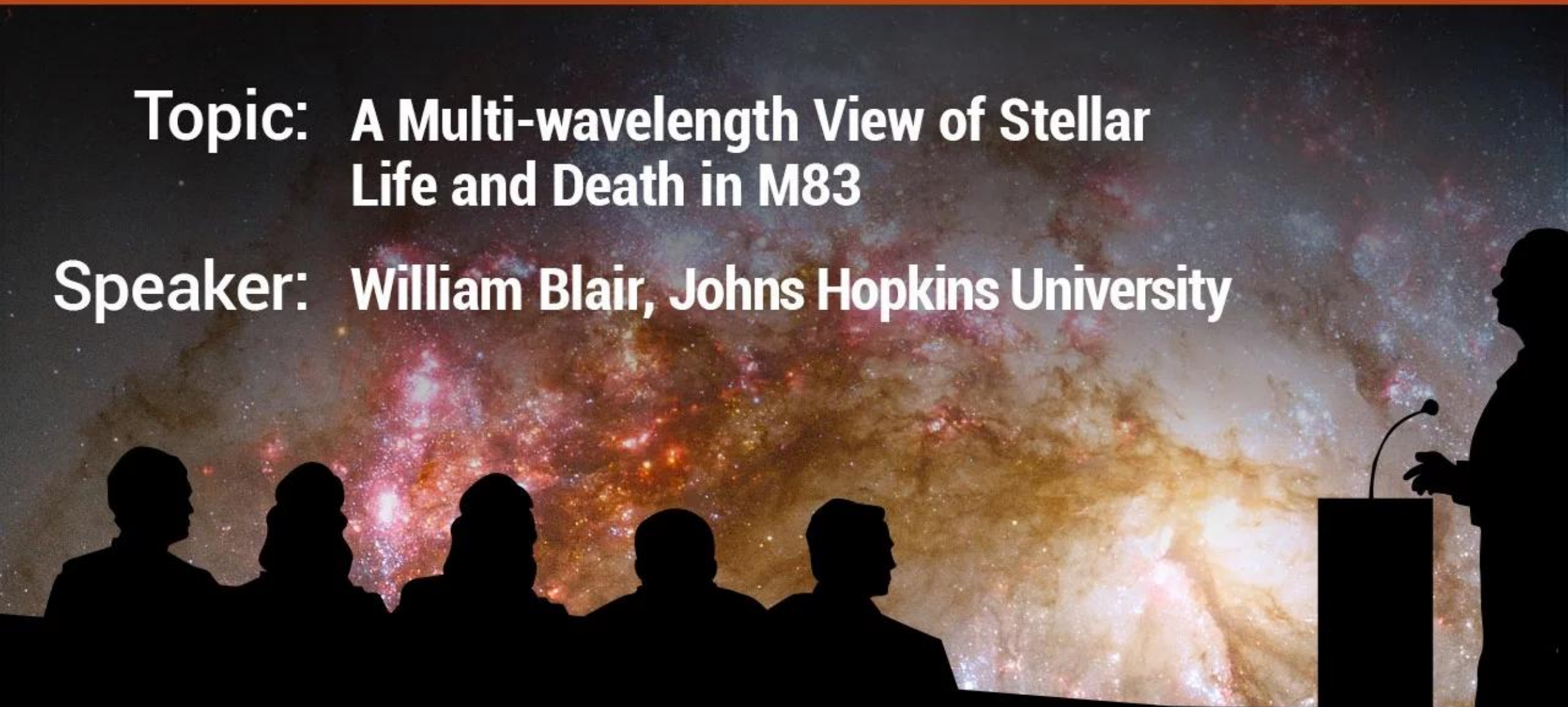


Hubble Public Lecture Series

**Topic: A Multi-wavelength View of Stellar
Life and Death in M83**

Speaker: William Blair, Johns Hopkins University



1
00:00:06,019 --> 00:00:03,220
I to study cosmology all right in

2
00:00:07,820 --> 00:00:06,029
December Christine Chen will be talking

3
00:00:11,450 --> 00:00:07,830
about debris disks and the evolution of

4
00:00:14,450 --> 00:00:11,460
planetary systems yet another one of the

5
00:00:16,640 --> 00:00:14,460
hot topics in astronomy talking about

6
00:00:19,640 --> 00:00:16,650
extrasolar planets and how planetary

7
00:00:24,950 --> 00:00:19,650
systems develop I mean I remember when I

8
00:00:26,450 --> 00:00:24,960
was a wee lad just an undergraduate we

9
00:00:28,550 --> 00:00:26,460
knew nothing about how planetary systems

10
00:00:30,470 --> 00:00:28,560
develop and the amount that we know now

11
00:00:31,540 --> 00:00:30,480
is just amazing it's one of the one of

12
00:00:33,889 --> 00:00:31,550
the great topics

13
00:00:38,389 --> 00:00:33,899

unfortunately in January we have our

14

00:00:40,160 --> 00:00:38,399

favors speaker TBA because it's hard to

15

00:00:42,950 --> 00:00:40,170

get somebody just after New Year's I

16

00:00:45,290 --> 00:00:42,960

wanted to ask Li asked a question folks

17

00:00:48,200 --> 00:00:45,300

would you prefer that we delayed this

18

00:00:51,080 --> 00:00:48,210

until January 10th instead of January

19

00:00:51,920 --> 00:00:51,090

3rd or would that or would that not make

20

00:00:55,180 --> 00:00:51,930

a difference

21

00:00:57,590 --> 00:00:55,190

anybody think it would be good to delay

22

00:01:00,529 --> 00:00:57,600

anybody okay with everybody would just

23

00:01:03,920 --> 00:01:00,539

think the third is better and who

24

00:01:06,880 --> 00:01:03,930

doesn't really care okay overwhelming

25

00:01:10,539 --> 00:01:06,890

don't care a little bit towards the

26

00:01:12,980 --> 00:01:10,549

towards the January 10th because the

27

00:01:15,260 --> 00:01:12,990

American Astronomical Society meets the

28

00:01:16,789 --> 00:01:15,270

first week of January and I often have

29

00:01:19,490 --> 00:01:16,799

trouble getting speakers because half

30

00:01:22,940 --> 00:01:19,500

the Institute is out at the conference

31

00:01:25,640 --> 00:01:22,950

so I might some I might consider

32

00:01:27,350 --> 00:01:25,650

delaying that all right oh the

33

00:01:28,850 --> 00:01:27,360

construction update hopefully you guys

34

00:01:30,469 --> 00:01:28,860

had to come a different way to get here

35

00:01:32,870 --> 00:01:30,479

hopefully obviously you made it

36

00:01:34,429 --> 00:01:32,880

hopefully there isn't another 50 people

37

00:01:37,039 --> 00:01:34,439

out there getting lost

38

00:01:40,700 --> 00:01:37,049

if so hopefully they will find their way

39

00:01:44,210 --> 00:01:40,710

in you have to come from the south

40

00:01:47,179 --> 00:01:44,220

because north of it is closed here is

41

00:01:49,280 --> 00:01:47,189

the map this blue part is the stuff

42

00:01:51,469 --> 00:01:49,290

that's done looks real nice especially

43

00:01:53,660 --> 00:01:51,479

this path along here is a really nice

44

00:01:56,149 --> 00:01:53,670

little path if you see it when you're

45

00:01:58,969 --> 00:01:56,159

during the daylight but this yellow

46

00:02:01,670 --> 00:01:58,979

section here and this red section up

47

00:02:03,920 --> 00:02:01,680

here those are now closed and will be

48

00:02:05,810 --> 00:02:03,930

through December ok so for the next

49

00:02:08,540 --> 00:02:05,820

several months you'll have to approach

50

00:02:12,140 --> 00:02:08,550

from the south it definitely has length

51
00:02:13,460 --> 00:02:12,150
into my commute our website with

52
00:02:15,440 --> 00:02:13,470
information

53
00:02:17,180 --> 00:02:15,450
is if you look if you just take your

54
00:02:19,850 --> 00:02:17,190
favorite search engine and look for

55
00:02:22,790 --> 00:02:19,860
Hubble public talks you'll find it we

56
00:02:25,670 --> 00:02:22,800
have links to our live webcasting both

57
00:02:28,070 --> 00:02:25,680
on YouTube and on the STScI webcasting

58
00:02:30,020 --> 00:02:28,080
site our archives of the past lectures

59
00:02:32,270 --> 00:02:30,030
again on YouTube and the STScI

60
00:02:34,610 --> 00:02:32,280
webcasting and a feature that has been

61
00:02:37,220 --> 00:02:34,620
used an awful lot because I get an email

62
00:02:39,680 --> 00:02:37,230
every time it is used people signing up

63
00:02:42,280 --> 00:02:39,690

for our announcements

64

00:02:45,110 --> 00:02:42,290

thank you all for signing up but it

65

00:02:47,120 --> 00:02:45,120

makes my job a lot easier in getting the

66

00:02:49,190 --> 00:02:47,130

information out to people not only

67

00:02:51,800 --> 00:02:49,200

around the Baltimore area but across the

68

00:02:54,980 --> 00:02:51,810

country we also of course have our list

69

00:02:57,050 --> 00:02:54,990

of upcoming lectures so visit our

70

00:03:00,170 --> 00:02:57,060

website to find that all that wonderful

71

00:03:02,000 --> 00:03:00,180

information announcements well I'll just

72

00:03:04,520 --> 00:03:02,010

use our website because there is mail

73

00:03:07,340 --> 00:03:04,530

list at STScl dat edu but it's much more

74

00:03:09,170 --> 00:03:07,350

difficult just use our website if you

75

00:03:12,430 --> 00:03:09,180

want to contact us you can send an email

76

00:03:16,460 --> 00:03:12,440

to public lecture at stsci edu ask

77

00:03:19,160 --> 00:03:16,470

comments or questions we are also on

78

00:03:22,850 --> 00:03:19,170

social media Facebook to Twitter

79

00:03:24,949 --> 00:03:22,860

accounts Google Pinterest I will note

80

00:03:26,720 --> 00:03:24,959

that my Hubble's universe unfiltered

81

00:03:30,050 --> 00:03:26,730

blog and Hubble site is getting updated

82

00:03:31,970 --> 00:03:30,060

more frequently we have it's the new

83

00:03:33,620 --> 00:03:31,980

fiscal year the funding for this fiscal

84

00:03:36,770 --> 00:03:33,630

year has enabled me to put more time

85

00:03:39,500 --> 00:03:36,780

into my blog I'm putting I put up three

86

00:03:42,050 --> 00:03:39,510

posts last month I also do Facebook

87

00:03:45,110 --> 00:03:42,060

Google and Twitter every now and then I

88

00:03:48,979 --> 00:03:45,120

don't promise to be daily at all hunt

89

00:03:50,720 --> 00:03:48,989

something like that Observatory I do not

90

00:03:52,670 --> 00:03:50,730

I didn't check my email late this

91

00:03:57,229 --> 00:03:52,680

afternoon the person from the

92

00:03:59,630 --> 00:03:57,239

observatory is obviously not here remind

93

00:04:01,400 --> 00:03:59,640

me to ask again at the end to see if

94

00:04:05,479 --> 00:04:01,410

they are here to take us up to the

95

00:04:09,380 --> 00:04:05,489

observatory tonight okay and now news

96

00:04:15,380 --> 00:04:09,390

from the universe for October 2016

97

00:04:17,360 --> 00:04:15,390

our first story lovely plumage on Europa

98

00:04:21,140 --> 00:04:17,370

how many of you recognize the phrase

99

00:04:23,270 --> 00:04:21,150

lovely plumage alright oh not that many

100

00:04:26,510 --> 00:04:23,280

oh oh this isn't a reference for this

101
00:04:27,090 --> 00:04:26,520
audience all right this is from the dead

102
00:04:30,050 --> 00:04:27,100
parrot

103
00:04:32,610 --> 00:04:30,060
sketch of Monty Python's Flying Circus

104
00:04:35,400 --> 00:04:32,620
where John Cleese's

105
00:04:37,980 --> 00:04:35,410
customer comes in to return a parrot

106
00:04:40,620 --> 00:04:37,990
that is dead and Michael Palin as the

107
00:04:42,330 --> 00:04:40,630
shop owner tries to refuse to

108
00:04:45,240 --> 00:04:42,340
acknowledge that the parrot is dead

109
00:04:48,540 --> 00:04:45,250
saying all the Norwegian blues lovely

110
00:04:51,030 --> 00:04:48,550
plumage and just talks about how it is

111
00:04:54,570 --> 00:04:51,040
you know you know it's just resting it's

112
00:04:57,420 --> 00:04:54,580
pining for the fjords and such this is

113
00:05:00,150 --> 00:04:57,430

an extremely famous sketch amongst Monty

114

00:05:03,630 --> 00:05:00,160

Python fans so much so that when Monty

115

00:05:08,360 --> 00:05:03,640

Python had a reunion in London it was

116

00:05:13,620 --> 00:05:08,370

celebrated with a 50-foot dead parrot

117

00:05:15,060 --> 00:05:13,630

the Tower Bridge so lovely plumage has

118

00:05:19,200 --> 00:05:15,070

very little to do with this story I just

119

00:05:24,900 --> 00:05:19,210

wanted to show this image but the plumes

120

00:05:27,930 --> 00:05:24,910

on Europa are these and they're not

121

00:05:29,820 --> 00:05:27,940

really quite so lovely to look at

122

00:05:33,240 --> 00:05:29,830

matter of fact you may not even see them

123

00:05:36,240 --> 00:05:33,250

unless I put in the arrows okay all

124

00:05:38,700 --> 00:05:36,250

right so this is a an image of Europa

125

00:05:41,550 --> 00:05:38,710

from the Galileo mission it's a a mosaic

126

00:05:44,070 --> 00:05:41,560

put together and these are the plumes

127

00:05:47,430 --> 00:05:44,080

down here in white the background is

128

00:05:49,470 --> 00:05:47,440

from the Hubble instrument okay oh and

129

00:05:51,270 --> 00:05:49,480

you're seeing this white stuff down here

130

00:05:55,620 --> 00:05:51,280

and it's kind of pixelated and stuff and

131

00:05:59,310 --> 00:05:55,630

I wouldn't call it lovely they're kind

132

00:06:02,490 --> 00:05:59,320

of ratty except there is a really lovely

133

00:06:04,680 --> 00:06:02,500

science story behind it so let me

134

00:06:07,440 --> 00:06:04,690

explain the science behind it and you'll

135

00:06:10,290 --> 00:06:07,450

see how beautiful they really can be so

136

00:06:12,690 --> 00:06:10,300

this is Jupiter's moon Europa it's the

137

00:06:16,110 --> 00:06:12,700

smallest of the four Galilean moons okay

138

00:06:20,370 --> 00:06:16,120

and we believe its interior structure

139

00:06:20,730 --> 00:06:20,380

has an iron core metallic core it has a

140

00:06:24,780 --> 00:06:20,740

whoops

141

00:06:29,280 --> 00:06:24,790

it has a rocky section and then it has

142

00:06:32,040 --> 00:06:29,290

an liquid water ocean and an icy crust

143

00:06:35,070 --> 00:06:32,050

okay due to various measurements in the

144

00:06:38,300 --> 00:06:35,080

magnetic field of motion to it we

145

00:06:40,830 --> 00:06:38,310

believe there is a liquid water ocean

146

00:06:44,250 --> 00:06:40,840

subsurface on Europa

147

00:06:47,250 --> 00:06:44,260

the question is is how thick is this ice

148

00:06:49,560 --> 00:06:47,260

layer is it 10 kilometers thick or is it

149

00:06:51,420 --> 00:06:49,570

100 kilometers thick we're not exactly

150

00:06:55,050 --> 00:06:51,430

sure there are two camps that argue

151
00:06:58,200 --> 00:06:55,060
about this but when we look at Europa's

152
00:07:02,010 --> 00:06:58,210
surface this is your opus surface we see

153
00:07:04,170 --> 00:07:02,020
a modeled ice sea surface and this is

154
00:07:06,900 --> 00:07:04,180
the famous ice rafts picture taken by

155
00:07:10,050 --> 00:07:06,910
the Galileo satellite which looks a lot

156
00:07:13,920 --> 00:07:10,060
like the broken ice structures in around

157
00:07:15,659 --> 00:07:13,930
the North Pole okay on earth indicating

158
00:07:18,870 --> 00:07:15,669
that there might be the same sort of

159
00:07:21,750 --> 00:07:18,880
motion of you know perhaps not on top of

160
00:07:23,129 --> 00:07:21,760
a shallow water layer just underneath as

161
00:07:25,440 --> 00:07:23,139
we have here on earth

162
00:07:26,820 --> 00:07:25,450
but that there might be softer ice and

163
00:07:30,060 --> 00:07:26,830

there's some sort of motion there's some

164

00:07:34,440 --> 00:07:30,070

breakup and a in motion through it okay

165

00:07:38,820 --> 00:07:34,450

we have evidence of motion of were sort

166

00:07:40,290 --> 00:07:38,830

of ice tectonics on Europa and it's look

167

00:07:43,409 --> 00:07:40,300

and it's something like this where we've

168

00:07:46,260 --> 00:07:43,419

got these subsumption bands here what we

169

00:07:49,409 --> 00:07:46,270

believe is happening is the cold outer

170

00:07:51,110 --> 00:07:49,419

ice shell is actually subducting just

171

00:07:53,850 --> 00:07:51,120

like the plates abduct on earth

172

00:07:57,540 --> 00:07:53,860

subducting below another ice layer

173

00:08:00,570 --> 00:07:57,550

alright and so this is denser and it

174

00:08:03,120 --> 00:08:00,580

drops down into the deeper warmer ice

175

00:08:05,460 --> 00:08:03,130

okay and notice that they call this the

176

00:08:07,529 --> 00:08:05,470

connecting portion of the ice shell

177

00:08:10,290 --> 00:08:07,539

alright we sort of think of ice as rigid

178

00:08:12,659 --> 00:08:10,300

and fixed but on your rope but there

179

00:08:14,940 --> 00:08:12,669

actually is motion through the ice and

180

00:08:17,430 --> 00:08:14,950

they talk about it convecting with the

181

00:08:20,520 --> 00:08:17,440

liquid ocean being underneath that ice

182

00:08:23,580 --> 00:08:20,530

layer again how thick is this ice layer

183

00:08:25,860 --> 00:08:23,590

we're not sure so it shows there is at

184

00:08:28,200 --> 00:08:25,870

least motion in the ice on your rope up

185

00:08:31,620 --> 00:08:28,210

and there's water deep underneath and

186

00:08:34,860 --> 00:08:31,630

the question is well how much that water

187

00:08:37,339 --> 00:08:34,870

gets up near the surface because if we

188

00:08:40,100 --> 00:08:37,349

want to check for life in the universe

189

00:08:43,260 --> 00:08:40,110

we need three things we need energy

190

00:08:46,260 --> 00:08:43,270

carbon and water that's what that's what

191

00:08:49,170 --> 00:08:46,270

life as we know it requires well energy

192

00:08:52,050 --> 00:08:49,180

and carbon are pretty easy to find water

193

00:08:53,490 --> 00:08:52,060

is really really hard to find so you

194

00:08:54,390 --> 00:08:53,500

rope out where we know there is some

195

00:08:56,910 --> 00:08:54,400

water

196

00:08:59,640 --> 00:08:56,920

is a place to look to see if life could

197

00:09:05,340 --> 00:08:59,650

have developed even microbial life on

198

00:09:07,980 --> 00:09:05,350

Europa alright so we have actually seen

199

00:09:08,940 --> 00:09:07,990

water plumes on another moon this is

200

00:09:10,320 --> 00:09:08,950

Saturn's moons

201
00:09:12,690 --> 00:09:10,330
Enceladus by the way this is Saturn's

202
00:09:13,860 --> 00:09:12,700
rings up here okay a nice edge on view

203
00:09:15,750 --> 00:09:13,870
of the Rings and this is from the

204
00:09:18,660 --> 00:09:15,760
Cassini satellite where you can see

205
00:09:23,430 --> 00:09:18,670
these plumes coming from Saturn's moon

206
00:09:26,850 --> 00:09:23,440
Enceladus alright and we've also seen

207
00:09:31,230 --> 00:09:26,860
indications of possible plumes on Europa

208
00:09:34,050 --> 00:09:31,240
from Hubble now Hubble did not see water

209
00:09:37,980 --> 00:09:34,060
plumes this was in 2012 what Hubble

210
00:09:41,040 --> 00:09:37,990
instead saw was auroral emissions from

211
00:09:45,420 --> 00:09:41,050
hydrogen and oxygen what is water

212
00:09:48,300 --> 00:09:45,430
composed of h₂o hydrogen and oxygen so

213
00:09:51,180 --> 00:09:48,310

these are a rural emissions associated

214

00:09:53,880 --> 00:09:51,190

with Europa from hydrogen and oxygen

215

00:09:57,150 --> 00:09:53,890

which are indicative that there might be

216

00:09:59,550 --> 00:09:57,160

water plumes so how are we going to look

217

00:10:02,180 --> 00:09:59,560

for them well we're going to be tricky

218

00:10:06,150 --> 00:10:02,190

and we're going to look for them as

219

00:10:09,120 --> 00:10:06,160

Europa goes into transit in front of

220

00:10:12,660 --> 00:10:09,130

Jupiter that way we get the bright

221

00:10:17,310 --> 00:10:12,670

background of Jupiter in order to back

222

00:10:20,880 --> 00:10:17,320

illuminate Europa in order to search for

223

00:10:23,340 --> 00:10:20,890

these plumes so here are the actual

224

00:10:26,640 --> 00:10:23,350

images from the scientific paper as

225

00:10:28,190 --> 00:10:26,650

submitted all right so this background

226

00:10:34,200 --> 00:10:28,200

here is Jupiter

227

00:10:37,010 --> 00:10:34,210

this is Europa and here are some

228

00:10:39,990 --> 00:10:37,020

evidence of plumes here's another image

229

00:10:43,710 --> 00:10:40,000

again here is Europa here's some

230

00:10:46,500 --> 00:10:43,720

evidence of plumes as I said they're not

231

00:10:49,650 --> 00:10:46,510

pretty to look at but they indicate a

232

00:10:53,520 --> 00:10:49,660

really interesting story that there

233

00:10:57,210 --> 00:10:53,530

might be water plumes spewing out of

234

00:10:59,790 --> 00:10:57,220

Europa and we can then examine that

235

00:11:00,540 --> 00:10:59,800

water to see what is going on what is

236

00:11:02,700 --> 00:11:00,550

the chemistry

237

00:11:06,090 --> 00:11:02,710

what is the details of what may be going

238

00:11:07,519 --> 00:11:06,100

on and this internal ocean which if it's

239

00:11:09,650 --> 00:11:07,529

a hundred kilometers deep

240

00:11:12,679 --> 00:11:09,660

but below a below 100 kilometers of ice

241

00:11:14,629 --> 00:11:12,689

it's gonna be really hard to get down to

242

00:11:16,189 --> 00:11:14,639

okay you want to drill down 100

243

00:11:17,059 --> 00:11:16,199

kilometers to get to get to look at

244

00:11:19,579 --> 00:11:17,069

water ocean

245

00:11:21,410 --> 00:11:19,589

that's quite an engineering challenge if

246

00:11:23,449 --> 00:11:21,420

it's ten kilometres well I think that's

247

00:11:24,139 --> 00:11:23,459

a little bit easier it's still quite the

248

00:11:26,629 --> 00:11:24,149

challenge

249

00:11:29,629 --> 00:11:26,639

if however that water that water vapour

250

00:11:32,780 --> 00:11:29,639

is spewed out from the surface that's

251
00:11:34,939 --> 00:11:32,790
much much easier so this is an exciting

252
00:11:36,889 --> 00:11:34,949
announcement it is not absolutely a

253
00:11:42,290 --> 00:11:36,899
hundred percent confirmed that it is

254
00:11:44,239 --> 00:11:42,300
water plumes there all right but it does

255
00:11:46,489 --> 00:11:44,249
look like that there are water plumes

256
00:11:49,489 --> 00:11:46,499
coming from Europa and we will continue

257
00:11:52,579 --> 00:11:49,499
to study and have more information as we

258
00:11:54,860 --> 00:11:52,589
go this is an exciting idea of where

259
00:11:59,170 --> 00:11:54,870
we're going to look for potential life

260
00:12:02,660 --> 00:11:59,180
in our solar system our second story a

261
00:12:05,139 --> 00:12:02,670
smashing finale if you were here last

262
00:12:08,720 --> 00:12:05,149
month I talked about the Rosetta mission

263
00:12:10,189 --> 00:12:08,730

and the feel a lander that is in orbit

264

00:12:14,119 --> 00:12:10,199

around the comet 67p

265

00:12:16,759 --> 00:12:14,129

churyumov-gerasimenko all right yeah

266

00:12:19,749 --> 00:12:16,769

that's quite a mouthful to say and

267

00:12:23,720 --> 00:12:19,759

Rosetta is a mission that started in

268

00:12:26,869 --> 00:12:23,730

2004 it's been going for 12 years okay

269

00:12:29,509 --> 00:12:26,879

most of that time was spent in a very

270

00:12:32,269 --> 00:12:29,519

circuitous bunch of orbits just to get

271

00:12:34,519 --> 00:12:32,279

out to match orbits with the comet

272

00:12:37,129 --> 00:12:34,529

matter of fact it did a whole bunch of

273

00:12:41,509 --> 00:12:37,139

flybys in that process so it launched in

274

00:12:45,110 --> 00:12:41,519

March of 2004 it flew by earth in 2005

275

00:12:48,619 --> 00:12:45,120

Mars in 2007 earth in late 2007 the

276

00:12:53,629 --> 00:12:48,629

asteroid Stein's in 2008 earth again in

277

00:12:55,850 --> 00:12:53,639

2009 the asteroid leticia in July 2010

278

00:13:00,499 --> 00:12:55,860

and then spent four years matching

279

00:13:04,879 --> 00:13:00,509

orbits with comet 67p CG when it got

280

00:13:07,280 --> 00:13:04,889

there it found it was a contact binary

281

00:13:09,799 --> 00:13:07,290

comet which of course earned it the

282

00:13:16,040 --> 00:13:09,809

nickname comet rubber ducky for obvious

283

00:13:19,369 --> 00:13:16,050

reasons it has then since then and since

284

00:13:21,230 --> 00:13:19,379

its arrival in August 2014 the feel a

285

00:13:24,800 --> 00:13:21,240

lander was dropped down on

286

00:13:27,170 --> 00:13:24,810

November 2014 it stayed with the comet

287

00:13:29,449 --> 00:13:27,180

through its perihelion passage its

288

00:13:31,190 --> 00:13:29,459

closes passage by the Sun which is

289

00:13:33,889 --> 00:13:31,200

generally the most active time for a

290

00:13:35,690 --> 00:13:33,899

comet alright as it goes by the Sun most

291

00:13:37,130 --> 00:13:35,700

activities is going on there and it

292

00:13:40,430 --> 00:13:37,140

stayed with it for another year later

293

00:13:44,570 --> 00:13:40,440

and the mission ended last Friday

294

00:13:51,740 --> 00:13:44,580

September 30th 2016 with a very slow

295

00:13:55,940 --> 00:13:51,750

crash landing on 67p CG now you may

296

00:13:58,370 --> 00:13:55,950

remember that feel a landing was quite

297

00:14:01,970 --> 00:13:58,380

an event it was the only scientific

298

00:14:07,130 --> 00:14:01,980

event I know of that had a live blog by

299

00:14:09,949 --> 00:14:07,140

a webcomic xkcd the author of xkcd drew

300

00:14:12,920 --> 00:14:09,959

over a hundred different pictures to

301

00:14:15,350 --> 00:14:12,930

live blog the landing of feel a over the

302

00:14:16,760 --> 00:14:15,360

course of several hours as it was going

303

00:14:19,130 --> 00:14:16,770

so you can see here's the one I chose

304

00:14:22,250 --> 00:14:19,140

from time into landing three hours and

305

00:14:24,680 --> 00:14:22,260

he has all sorts of fun information and

306

00:14:25,340 --> 00:14:24,690

makes a make some make some good science

307

00:14:28,310 --> 00:14:25,350

jokes

308

00:14:31,370 --> 00:14:28,320

if you don't know xkcd it's a very very

309

00:14:32,780 --> 00:14:31,380

geek comic okay so if you want to grow

310

00:14:37,690 --> 00:14:32,790

up to be geeks guys in the front row

311

00:14:44,720 --> 00:14:41,990

the feel a lander however didn't happen

312

00:14:47,240 --> 00:14:44,730

the way it actually bounced the the the

313

00:14:48,800 --> 00:14:47,250

rockets that were were gonna the anchors

314

00:14:51,949 --> 00:14:48,810

that were gonna push into the comet

315

00:14:54,590 --> 00:14:51,959

didn't quite quite work and it was lost

316

00:14:57,560 --> 00:14:54,600

until as I showed you last month it was

317

00:15:00,170 --> 00:14:57,570

found in this little crag here the feel

318

00:15:02,870 --> 00:15:00,180

a lander was finally discovered as the

319

00:15:05,449 --> 00:15:02,880

Rosetta orbiter got close in enough to

320

00:15:07,970 --> 00:15:05,459

actually see in search for it and found

321

00:15:11,780 --> 00:15:07,980

it so there's the last resting place of

322

00:15:14,050 --> 00:15:11,790

feel a of course the Rosetta orbiter

323

00:15:18,800 --> 00:15:14,060

itself

324

00:15:21,110 --> 00:15:18,810

joined it last Friday but what if I

325

00:15:23,150 --> 00:15:21,120

remember this most about this mission is

326
00:15:23,870 --> 00:15:23,160
not going to be these images I'm going

327
00:15:27,519 --> 00:15:23,880
to show you in a minute

328
00:15:31,250 --> 00:15:27,529
but really the number of really cool

329
00:15:34,130 --> 00:15:31,260
outburst images that Rosetta was able to

330
00:15:34,639 --> 00:15:34,140
get because it stayed with the comet for

331
00:15:40,100 --> 00:15:34,649
a year

332
00:15:42,079 --> 00:15:40,110
perihelion covering this active time in

333
00:15:44,269 --> 00:15:42,089
a life of the comet you can see all of

334
00:15:46,939 --> 00:15:44,279
these outbursts it was able to capture

335
00:15:49,639 --> 00:15:46,949
this is an immense data set that we will

336
00:15:50,629 --> 00:15:49,649
look at for years and and and even

337
00:15:53,660 --> 00:15:50,639
decades to come

338
00:15:55,910 --> 00:15:53,670

yes that was in The Wall Street The Wall

339

00:15:57,470 --> 00:15:55,920

Street Journal covered the the outburst

340

00:16:03,619 --> 00:15:57,480

because this is one of the great montage

341

00:16:06,309 --> 00:16:03,629

images well I'm glad to hear the Wall

342

00:16:09,710 --> 00:16:06,319

Street Journal Street Journal covers

343

00:16:13,819 --> 00:16:09,720

great science because this is an amazing

344

00:16:15,530 --> 00:16:13,829

amount of just amazing amount of

345

00:16:18,379 --> 00:16:15,540

observations compared to what we've had

346

00:16:20,239 --> 00:16:18,389

in terms of covering outbursts on comets

347

00:16:23,540 --> 00:16:20,249

okay and this this data set will be

348

00:16:26,179 --> 00:16:23,550

mined for years to come okay so they

349

00:16:29,299 --> 00:16:26,189

took 15 image they released 15 images of

350

00:16:31,460 --> 00:16:29,309

the descent of Rosetta over the last 24

351

00:16:33,679 --> 00:16:31,470

hours so in the lower-left this is the

352

00:16:35,840 --> 00:16:33,689

time to impact 23 hours 30 minutes for

353

00:16:38,030 --> 00:16:35,850

this first image and here's the height

354

00:16:41,840 --> 00:16:38,040

above the center of the comet 22.9

355

00:16:44,840 --> 00:16:43,280

and this is just a counting number so I

356

00:16:46,910 --> 00:16:44,850

can keep track

357

00:16:48,710 --> 00:16:46,920

downloading 15 images and keeping them

358

00:16:50,869 --> 00:16:48,720

the correct orders never caught in there

359

00:16:53,449 --> 00:16:50,879

oh it's not that easy alright so here

360

00:16:55,489 --> 00:16:53,459

you can see that a day before it's still

361

00:16:58,280 --> 00:16:55,499

you know you're seeing pretty much the

362

00:16:59,780 --> 00:16:58,290

comment you've got a you know a full

363

00:17:01,189 --> 00:16:59,790

sized view of the comment and you can

364

00:17:03,259 --> 00:17:01,199

see it's orbiting around the comet in

365

00:17:06,620 --> 00:17:03,269

the comet itself is turning the comet

366

00:17:08,480 --> 00:17:06,630

nucleus and as we start to get in now

367

00:17:11,630 --> 00:17:08,490

we're down just a little bit closer at

368

00:17:13,490 --> 00:17:11,640

20 kilometers and also these images go

369

00:17:15,860 --> 00:17:13,500

from the wide-angle view to the narrow

370

00:17:17,299 --> 00:17:15,870

angle view here you've got and start to

371

00:17:19,010 --> 00:17:17,309

see that you can see they're very craggy

372

00:17:23,179 --> 00:17:19,020

surface almost feels like it's sharp

373

00:17:26,120 --> 00:17:23,189

okay surface moving in you can see the

374

00:17:28,639 --> 00:17:26,130

sort of steps across there really

375

00:17:30,169 --> 00:17:28,649

interesting structures and then you've

376

00:17:32,210 --> 00:17:30,179

got a series of couple images where you

377

00:17:35,180 --> 00:17:32,220

can see this the same structures these

378

00:17:37,370 --> 00:17:35,190

are just relatively close in time you

379

00:17:40,519 --> 00:17:37,380

can see that structure here and you can

380

00:17:43,669 --> 00:17:40,529

see the structures it was moving through

381

00:17:45,649 --> 00:17:43,679

here then we get the what I think is the

382

00:17:46,980 --> 00:17:45,659

coolest image so we've been looking down

383

00:17:50,820 --> 00:17:46,990

on this

384

00:17:52,110 --> 00:17:50,830

then we get this image which looks like

385

00:17:54,960 --> 00:17:52,120

you're down on the surface of the comet

386

00:17:57,510 --> 00:17:54,970

right but what it has to be because

387

00:17:59,850 --> 00:17:57,520

you're 16 kilometers away from the comet

388

00:18:02,220 --> 00:17:59,860

this is the narrow angle camera right

389

00:18:04,200 --> 00:18:02,230

but what it has to be is whoops let me

390

00:18:07,320 --> 00:18:04,210

go back is that you're looking at one of

391

00:18:09,210 --> 00:18:07,330

these crags here from the side okay so

392

00:18:11,820 --> 00:18:09,220

as it orbits around the comet it's

393

00:18:14,370 --> 00:18:11,830

looking directly along here and you're

394

00:18:16,440 --> 00:18:14,380

looking in to see these crags sticking

395

00:18:18,419 --> 00:18:16,450

up and I actually think this is the

396

00:18:21,390 --> 00:18:18,429

coolest image of all of all the series

397

00:18:23,730 --> 00:18:21,400

of 15 because it just sort of gets you a

398

00:18:25,200 --> 00:18:23,740

feeling like you are there if you don't

399

00:18:28,590 --> 00:18:25,210

almost feel like you're walking on on

400

00:18:30,090 --> 00:18:28,600

the surface of the comet nucleus so this

401
00:18:35,490 --> 00:18:30,100
is kind of fun it looks a little bit

402
00:18:40,530 --> 00:18:35,500
like what's the there's a national park

403
00:18:42,270 --> 00:18:40,540
in the southwest Bryce Canyon that's it

404
00:18:44,130 --> 00:18:42,280
Bryce Canyon has a little bit of the

405
00:18:48,840 --> 00:18:44,140
hoodoo feel of Bryce Canyon National

406
00:18:50,340 --> 00:18:48,850
Park but Bryce Canyon doesn't it doesn't

407
00:18:55,070 --> 00:18:50,350
look that that rocky and in that case

408
00:18:57,180 --> 00:18:55,080
anyways so there is no erosion right

409
00:18:59,220 --> 00:18:57,190
exactly it couldn't be

410
00:19:00,810 --> 00:18:59,230
you couldn't have real hoodoos here

411
00:19:03,799 --> 00:19:00,820
because you wouldn't because dollars are

412
00:19:06,600 --> 00:19:03,809
produced by water erosion creating them

413
00:19:08,100 --> 00:19:06,610

this is I'm not an expert on the on this

414

00:19:09,000 --> 00:19:08,110

okay matter of fact I'll show you how

415

00:19:10,440 --> 00:19:09,010

much I'm an honor an expert because

416

00:19:12,600 --> 00:19:10,450

they've got a couple images here that

417

00:19:14,790 --> 00:19:12,610

I'm not exactly sure why they look like

418

00:19:16,590 --> 00:19:14,800

this either okay

419

00:19:18,650 --> 00:19:16,600

and then you can see as we're getting

420

00:19:22,169 --> 00:19:18,660

closer we're nine hours before impact

421

00:19:23,970 --> 00:19:22,179

okay and then we jump to almost six

422

00:19:25,950 --> 00:19:23,980

hours for impact and here you can again

423

00:19:28,080 --> 00:19:25,960

see these sort of striations structures

424

00:19:29,820 --> 00:19:28,090

okay which to me look like sedimentary

425

00:19:31,890 --> 00:19:29,830

stuff and I know it's not sedimentary

426

00:19:34,110 --> 00:19:31,900

stuff maybe it's produced by the

427

00:19:37,680 --> 00:19:34,120

collision of those to contact binary

428

00:19:39,270 --> 00:19:37,690

objects that form the contact binary so

429

00:19:41,360 --> 00:19:39,280

you've got this sort of striated stuff

430

00:19:45,150 --> 00:19:41,370

and then you get this sort of leather

431

00:19:47,040 --> 00:19:45,160

leathery type plane here okay and we

432

00:19:48,750 --> 00:19:47,050

have a lot of this type of plane that

433

00:19:53,280 --> 00:19:48,760

that we zooming in we're down 3 hours

434

00:19:56,070 --> 00:19:53,290

before impact ok moving in here here is

435

00:19:58,260 --> 00:19:56,080

the target area for where they're going

436

00:20:00,480 --> 00:19:58,270

to land it you can see that cliff along

437

00:20:03,270 --> 00:20:00,490

here three hours before impact

438

00:20:05,430 --> 00:20:03,280

six kilometers about the surface down to

439

00:20:07,650 --> 00:20:05,440

one point two kilometers you can see an

440

00:20:09,450 --> 00:20:07,660

edge with this very sharp sharp shadow

441

00:20:12,840 --> 00:20:09,460

here all right you're seeing the details

442

00:20:15,840 --> 00:20:12,850

and then the final image one minute

443

00:20:18,450 --> 00:20:15,850

before impact this is from 20 meters

444

00:20:22,320 --> 00:20:18,460

height I'm told this is about one meter

445

00:20:24,330 --> 00:20:22,330

across on the comet so it's out of focus

446

00:20:28,320 --> 00:20:24,340

because the cameras were never meant to

447

00:20:31,620 --> 00:20:28,330

focus 20 meters away from it and then

448

00:20:35,280 --> 00:20:31,630

boom the res that a signal was lost

449

00:20:40,230 --> 00:20:35,290

11:19 GMT here is the signal and there

450

00:20:43,730 --> 00:20:40,240

is not okay so the Rosetta mission will

451
00:20:46,560 --> 00:20:43,740
live on through it's amazing data set

452
00:20:49,920 --> 00:20:46,570
when I tweeted about this I said Rosetta

453
00:20:55,110 --> 00:20:49,930
is dead long live Rosetta because it

454
00:20:58,140 --> 00:20:55,120
really will have an amazing impact on

455
00:21:01,260 --> 00:20:58,150
cometary science however it will not

456
00:21:03,450 --> 00:21:01,270
have the kind of impact that people talk

457
00:21:07,080 --> 00:21:03,460
about in Hollywood movies so I'm gonna

458
00:21:09,750 --> 00:21:07,090
give the last word to xkcd who put out a

459
00:21:10,850 --> 00:21:09,760
Rosetta comic on Friday you can read it

460
00:21:13,890 --> 00:21:10,860
for yourself

461
00:21:16,920 --> 00:21:13,900
and it references the movie Armageddon

462
00:21:20,010 --> 00:21:16,930
in which they did try to blow up a

463
00:21:21,930 --> 00:21:20,020

comment to deflect it this was not meant

464

00:21:26,270 --> 00:21:21,940

to deflect the comet Bruce Willis was

465

00:21:36,780 --> 00:21:26,280

not required on the Rosetta mission okay

466

00:21:40,620 --> 00:21:36,790

any questions for yes okay so as the

467

00:21:42,990 --> 00:21:40,630

comet approaches the Sun it heats up and

468

00:21:47,910 --> 00:21:43,000

any pockets of volatiles that are near

469

00:21:48,480 --> 00:21:47,920

the surface can can it can can go from

470

00:21:51,750 --> 00:21:48,490

there

471

00:21:54,030 --> 00:21:51,760

isis state to gaseous state and blow out

472

00:21:55,980 --> 00:21:54,040

as Jets that's very common on comets

473

00:21:59,460 --> 00:21:55,990

matter of fact the what you're looking

474

00:22:01,860 --> 00:21:59,470

at with the 67p CG mostly is the comet

475

00:22:04,050 --> 00:22:01,870

nucleus okay but what you usually think

476
00:22:06,510 --> 00:22:04,060
of the knew of a comet is this big fuzzy

477
00:22:08,790 --> 00:22:06,520
ball well that's the coma that's all the

478
00:22:11,040 --> 00:22:08,800
gases that have have come out from the

479
00:22:14,049 --> 00:22:11,050
comet all right and then you get that

480
00:22:15,729 --> 00:22:14,059
those gases get swept back into a tail

481
00:22:18,249 --> 00:22:15,739
and that's what produces your standard

482
00:22:21,399 --> 00:22:18,259
idea of a comment what we're studying

483
00:22:24,190 --> 00:22:21,409
here is really the comet nucleus and

484
00:22:26,649 --> 00:22:24,200
those outbursts are the gases that are

485
00:22:30,519 --> 00:22:26,659
that are bursting out it the perihelion

486
00:22:32,979 --> 00:22:30,529
for 67p is only one point two times the

487
00:22:34,739 --> 00:22:32,989
Earth's distance to the Sun so it never

488
00:22:38,200 --> 00:22:34,749

gets really really close to the Sun

489

00:22:40,180 --> 00:22:38,210

therefore it doesn't doesn't burst out

490

00:22:42,009 --> 00:22:40,190

that much and it doesn't produce a coma

491

00:22:45,190 --> 00:22:42,019

it's a short period comet only has a six

492

00:22:47,320 --> 00:22:45,200

point four year period so it doesn't

493

00:22:50,739 --> 00:22:47,330

develop a big long tail like you may

494

00:22:53,079 --> 00:22:50,749

have seen with comet hale-bopp or the

495

00:22:54,759 --> 00:22:53,089

way we depict comet West or comet

496

00:22:57,669 --> 00:22:54,769

aquellas ecchi or other of these

497

00:22:59,469 --> 00:22:57,679

spectacular comets this is just your

498

00:23:00,039 --> 00:22:59,479

normal ordinary run-of-the-mill boring

499

00:23:04,749 --> 00:23:00,049

comet

500

00:23:07,419 --> 00:23:04,759

boring they are that ice ball nucleus

501
00:23:09,489 --> 00:23:07,429
with the Jets coming out and not these

502
00:23:11,680 --> 00:23:09,499
big huge tails that last that stretch

503
00:23:17,769 --> 00:23:11,690
for millions of kilometres good question

504
00:23:19,869 --> 00:23:17,779
thank you yes it's ice and rock it's ice

505
00:23:21,700 --> 00:23:19,879
and rock I usually usually think of them

506
00:23:34,180 --> 00:23:21,710
as ice balls but we know if we actually

507
00:23:38,259 --> 00:23:34,190
know yes they are ice and rock yes it

508
00:23:40,719 --> 00:23:38,269
could be I say it does look a lot like

509
00:23:42,909 --> 00:23:40,729
rocks scatter and you will expose my

510
00:23:45,690 --> 00:23:42,919
ignorance on the commentary services

511
00:23:48,459 --> 00:23:45,700
we've never seen commentary surfaces and

512
00:23:51,669 --> 00:23:48,469
that incredible detail we actually you

513
00:23:53,169 --> 00:23:51,679

know with Pluto last year and the the

514

00:23:55,629 --> 00:23:53,179

Deep Impact mission that we did a few

515

00:23:57,519 --> 00:23:55,639

years ago and this we're learning so

516

00:23:59,529 --> 00:23:57,529

much and actually what we're seeing on

517

00:24:02,950 --> 00:23:59,539

Europa as well we're learning so much

518

00:24:05,079 --> 00:24:02,960

about Isis and how they behave out in

519

00:24:06,310 --> 00:24:05,089

the solar system we're just seeing you

520

00:24:10,169 --> 00:24:06,320

know cryovolcanism

521

00:24:15,639 --> 00:24:10,179

on on Pluto the kraaho tectonics on

522

00:24:17,589 --> 00:24:15,649

Europa and so how these ices interact is

523

00:24:20,109 --> 00:24:17,599

something that that's actually pretty

524

00:24:21,249 --> 00:24:20,119

new and I think it's a quite an

525

00:24:22,109 --> 00:24:21,259

interesting field that has developed

526

00:24:25,719 --> 00:24:22,119

lately

527

00:24:27,129 --> 00:24:25,729

alright I well I have to I have to get

528

00:24:27,930 --> 00:24:27,139

to Bill's talk otherwise we'll be here

529

00:24:30,360 --> 00:24:27,940

wait

530

00:24:33,450 --> 00:24:30,370

late alright so let me go to our

531

00:24:35,999 --> 00:24:33,460

featured speaker and our featured

532

00:24:39,060 --> 00:24:36,009

speaker tonight is Bill Blair from the

533

00:24:40,889 --> 00:24:39,070

Johns Hopkins University and it is Johns

534

00:24:44,039 --> 00:24:40,899

Hopkins make sure everybody in Baltimore

535

00:24:47,009 --> 00:24:44,049

knows that okay bill has been there and

536

00:24:48,930 --> 00:24:47,019

he told me since 1984 and I was like he

537

00:24:50,869 --> 00:24:48,940

doesn't look old enough to have been

538

00:24:57,810 --> 00:24:50,879

around since my teenager

539

00:25:00,570 --> 00:24:57,820

yes he got his PhD at 12 he has worked

540

00:25:02,909 --> 00:25:00,580

on several major instruments the Hopkins

541

00:25:05,100 --> 00:25:02,919

ultraviolet telescope that flew on the

542

00:25:06,659 --> 00:25:05,110

Space Shuttle twice we had hoped it

543

00:25:09,240 --> 00:25:06,669

would fly a few more times on the space

544

00:25:12,240 --> 00:25:09,250

shuttle and then he moved over to the

545

00:25:15,990 --> 00:25:12,250

Far all Tobias copic Explorer also

546

00:25:19,259 --> 00:25:16,000

called fuse working in as you can see in

547

00:25:21,779 --> 00:25:19,269

ultraviolet and now he has moved to

548

00:25:24,480 --> 00:25:21,789

infrared he most of his time is spent

549

00:25:29,100 --> 00:25:24,490

now on the James Webb Space Telescope

550

00:25:30,389 --> 00:25:29,110

and I don't know what else to say it

551
00:25:33,060 --> 00:25:30,399
he's a really great guy I think you're

552
00:25:39,090 --> 00:25:33,070
gonna enjoy his talk tonight ladies and

553
00:25:45,400 --> 00:25:42,010
thank you very much it's a great

554
00:25:46,990 --> 00:25:45,410
pleasure to be here tonight to tell you

555
00:25:49,510 --> 00:25:47,000
about some research that I've been

556
00:25:51,010 --> 00:25:49,520
involved with most of my effort these

557
00:25:53,350 --> 00:25:51,020
days is functional work I'm actually

558
00:25:55,660 --> 00:25:53,360
working to help the Institute prepare

559
00:25:58,090 --> 00:25:55,670
for the James Webb telescope and prepare

560
00:25:59,920 --> 00:25:58,100
the the ground system is called the

561
00:26:02,050 --> 00:25:59,930
software and the systems that will

562
00:26:04,510 --> 00:26:02,060
support the James Webb telescope and

563
00:26:07,540 --> 00:26:04,520

astronomers - proposed for the James

564

00:26:09,520 --> 00:26:07,550

Webb telescope and so most of my effort

565

00:26:11,380 --> 00:26:09,530

is in meetings and that kind of stuff

566

00:26:13,150 --> 00:26:11,390

now but I do have a bunch of good

567

00:26:15,790 --> 00:26:13,160

collaborators and and over the last six

568

00:26:17,680 --> 00:26:15,800

or seven years we're partway through a

569

00:26:19,300 --> 00:26:17,690

research project that I'll eventually

570

00:26:20,800 --> 00:26:19,310

get to tonight I want to tell you some

571

00:26:23,860 --> 00:26:20,810

other things first before we get there

572

00:26:26,110 --> 00:26:23,870

on this galaxy m83 and in the background

573

00:26:29,620 --> 00:26:26,120

here you see what is a large mosaic

574

00:26:31,030 --> 00:26:29,630

image from the Hubble telescope some of

575

00:26:34,570 --> 00:26:31,040

the one the datasets that we took for

576

00:26:36,910 --> 00:26:34,580

this project to help us look for look at

577

00:26:38,830 --> 00:26:36,920

the star formation great huge amounts of

578

00:26:41,260 --> 00:26:38,840

star formation huge amounts of star

579

00:26:43,510 --> 00:26:41,270

formation going on in here and and then

580

00:26:45,520 --> 00:26:43,520

find the supernova remnants which is the

581

00:26:47,440 --> 00:26:45,530

stellar life the birth and evolution of

582

00:26:48,010 --> 00:26:47,450

stars and then the stellar gases the

583

00:26:50,920 --> 00:26:48,020

backend

584

00:26:52,060 --> 00:26:50,930

the supernova supernovae and the

585

00:26:55,720 --> 00:26:52,070

remnants the things that they leave

586

00:26:58,120 --> 00:26:55,730

behind and we try to study that galaxy

587

00:27:00,250 --> 00:26:58,130

and put it in context with our own Milky

588

00:27:04,440 --> 00:27:00,260

Way galaxy and other galaxies here in

589

00:27:08,800 --> 00:27:04,450

our local group for instance okay so

590

00:27:10,630 --> 00:27:08,810

before get to the the the meat of things

591

00:27:12,940 --> 00:27:10,640

here with the star formation and

592

00:27:15,040 --> 00:27:12,950

supernova remnants I want to spend a

593

00:27:18,040 --> 00:27:15,050

couple minutes giving you some context

594

00:27:19,710 --> 00:27:18,050

and tell you about how we find the

595

00:27:22,660 --> 00:27:19,720

supernova remnants in other galaxies

596

00:27:24,040 --> 00:27:22,670

we'll talk about what we see locally and

597

00:27:27,970 --> 00:27:24,050

what we're trying to find as we look

598

00:27:30,280 --> 00:27:27,980

farther away and then we'll get into m83

599

00:27:35,680 --> 00:27:30,290

itself and what we are finding and some

600

00:27:38,440 --> 00:27:35,690

ideas of of what it might mean so

601
00:27:40,090 --> 00:27:38,450
part of the context I like to do I like

602
00:27:42,910 --> 00:27:40,100
to try to do a few things to make big

603
00:27:44,590 --> 00:27:42,920
numbers understandable you know we hear

604
00:27:46,150 --> 00:27:44,600
so much you know in the public domain

605
00:27:48,160 --> 00:27:46,160
these days we hear millions and billions

606
00:27:49,540 --> 00:27:48,170
and trillions thrown around and they're

607
00:27:51,640 --> 00:27:49,550
just big numbers we just don't

608
00:27:53,710 --> 00:27:51,650
understand how big number

609
00:27:55,210 --> 00:27:53,720
really are and in astronomy of course we

610
00:27:57,850 --> 00:27:55,220
have to deal with a lot of big numbers

611
00:28:00,460 --> 00:27:57,860
we have the problem of distances I mean

612
00:28:03,040 --> 00:28:00,470
one light-year our yardstick that we use

613
00:28:05,890 --> 00:28:03,050

in in astronomy is some six trillion

614

00:28:09,160 --> 00:28:05,900

miles six times ten to the twelfth a six

615

00:28:11,620 --> 00:28:09,170

with 12 zeros miles in one light year

616

00:28:14,170 --> 00:28:11,630

and the nearest star is 4.3 light years

617

00:28:16,710 --> 00:28:14,180

away but the distances to quasars and

618

00:28:19,060 --> 00:28:16,720

galaxies are millions or billions of

619

00:28:21,250 --> 00:28:19,070

light-years and so these are just big

620

00:28:23,500 --> 00:28:21,260

numbers they kind of lose their context

621

00:28:25,420 --> 00:28:23,510

the same thing with discussion in the

622

00:28:27,700 --> 00:28:25,430

public domain when we talk about budgets

623

00:28:29,170 --> 00:28:27,710

and and this kind of thing and I think

624

00:28:31,210 --> 00:28:29,180

part of the problem is you know we kind

625

00:28:32,680 --> 00:28:31,220

of here million billion trillion and we

626

00:28:34,720 --> 00:28:32,690

think they're kind of factors of 10

627

00:28:37,180 --> 00:28:34,730

apart but they're not they're factors of

628

00:28:39,370 --> 00:28:37,190

a thousand apart you know it's a

629

00:28:42,520 --> 00:28:39,380

thousand millions make a billion and a

630

00:28:44,920 --> 00:28:42,530

thousand billions to make a trillion

631

00:28:47,530 --> 00:28:44,930

okay so I thought I would just do a

632

00:28:51,820 --> 00:28:47,540

little exercise to give you some idea of

633

00:28:55,450 --> 00:28:51,830

how big a billion is okay so I have some

634

00:28:56,770 --> 00:28:55,460

props here I have a ream of paper I want

635

00:28:59,170 --> 00:28:56,780

you to use your imagination here a

636

00:29:00,880 --> 00:28:59,180

little bit okay so Rina Rina paper has

637

00:29:05,620 --> 00:29:00,890

how many how many sheets of paper in a

638

00:29:08,560 --> 00:29:05,630

ream you know 500 500 sheets okay let's

639

00:29:10,140 --> 00:29:08,570

assume every sheet of paper in here is a

640

00:29:15,250 --> 00:29:10,150

hundred dollar bill

641

00:29:19,360 --> 00:29:15,260

that's 50 thousand dollars right there

642

00:29:20,920 --> 00:29:19,370

okay so if I take two of those we got a

643

00:29:23,110 --> 00:29:20,930

hundred thousand dollars so that's a

644

00:29:26,260 --> 00:29:23,120

little easier to go by factors of 10

645

00:29:28,960 --> 00:29:26,270

from so there's two there's a hundred

646

00:29:32,650 --> 00:29:28,970

thousand dollars \$100 bills side by side

647

00:29:35,140 --> 00:29:32,660

and I got a yardstick here that happens

648

00:29:40,090 --> 00:29:35,150

to be about four inches okay so four

649

00:29:43,630 --> 00:29:40,100

inches of paper is like \$100,000 so ten

650

00:29:44,950 --> 00:29:43,640

times that is a million dollars okay if

651

00:29:47,830 --> 00:29:44,960

we had the stack of paper that high

652

00:29:50,200 --> 00:29:47,840

that's a meter stick 40 inches that

653

00:29:52,060 --> 00:29:50,210

would be a million dollars so \$100 bills

654

00:29:55,660 --> 00:29:52,070

stacked up to there there's a million

655

00:30:00,720 --> 00:29:55,670

dollars a billion dollars is a thousand

656

00:30:02,529 --> 00:30:00,730

times that a kilometer 6/10 of a mile

657

00:30:04,629 --> 00:30:02,539

okay

658

00:30:06,099 --> 00:30:04,639

so when you're here so you still I could

659

00:30:08,739 --> 00:30:06,109

pick a random number out of the you know

660

00:30:13,060 --> 00:30:08,749

the the news you know nine hundred

661

00:30:15,699 --> 00:30:13,070

thirteen million that's over half a mile

662

00:30:17,019 --> 00:30:15,709

high stack of \$100 bills folks so that's

663

00:30:19,659 --> 00:30:17,029

that's a big number

664

00:30:21,699 --> 00:30:19,669

okay big numbers that so let's do one

665

00:30:23,589 --> 00:30:21,709

more thing let's go one more step look

666

00:30:25,329 --> 00:30:23,599

instead of money let's talk about time

667

00:30:27,819 --> 00:30:25,339

because time is another thing in

668

00:30:29,859 --> 00:30:27,829

astronomy that gets pretty pretty hairy

669

00:30:31,989 --> 00:30:29,869

for us and it's because there's such a

670

00:30:33,579 --> 00:30:31,999

dichotomy between our experience of time

671

00:30:37,479 --> 00:30:33,589

we're like a hundred years is a long

672

00:30:40,359 --> 00:30:37,489

time to us but to realize that a million

673

00:30:42,759 --> 00:30:40,369

years or in some context even a billion

674

00:30:45,249 --> 00:30:42,769

years in astronomy is considered a short

675

00:30:48,369 --> 00:30:45,259

time because this universe itself is

676
00:30:50,979 --> 00:30:48,379
13.8 billion years and so you're looking

677
00:30:52,989 --> 00:30:50,989
at the evolution of galaxies from early

678
00:30:54,519 --> 00:30:52,999
times on you know a billion years is

679
00:30:57,069 --> 00:30:54,529
really not that long

680
00:30:58,749 --> 00:30:57,079
believe it or not right so we could do

681
00:31:00,939 --> 00:30:58,759
that same thing let's take one sheet of

682
00:31:03,059 --> 00:31:00,949
paper and this is now a time line okay

683
00:31:05,439 --> 00:31:03,069
one sheet of paper is a hundred years a

684
00:31:08,409 --> 00:31:05,449
like a human lifetime a long human

685
00:31:12,159 --> 00:31:08,419
lifetime okay well then a million years

686
00:31:16,719 --> 00:31:12,169
is that big and a billion years is the

687
00:31:20,169 --> 00:31:16,729
6/10 of a mile one kilometer tall so

688
00:31:22,629 --> 00:31:20,179

this is a short time in astronomy one

689

00:31:24,579 --> 00:31:22,639

sheet of paper is a long time to us and

690

00:31:27,069 --> 00:31:24,589

that's why we sometimes have a hard time

691

00:31:29,019 --> 00:31:27,079

communicating these big these big

692

00:31:32,589 --> 00:31:29,029

numbers well so now we're going to look

693

00:31:34,389 --> 00:31:32,599

at star formation in m83 you collapsed a

694

00:31:35,559 --> 00:31:34,399

cloud of gas and dust it creates a whole

695

00:31:38,919 --> 00:31:35,569

bunch of stars there are a whole range

696

00:31:41,489 --> 00:31:38,929

of different masses the big massive

697

00:31:43,839 --> 00:31:41,499

stars only live for a few million years

698

00:31:45,639 --> 00:31:43,849

short time ok

699

00:31:47,229 --> 00:31:45,649

whereas I mean our Sun we know is

700

00:31:48,729 --> 00:31:47,239

four-and-a-half billion years there's

701
00:31:51,489 --> 00:31:48,739
only maybe about halfway through its

702
00:31:53,919 --> 00:31:51,499
lifetime so the low mass stars that form

703
00:31:56,349 --> 00:31:53,929
will stay around almost almost forever

704
00:31:58,479 --> 00:31:56,359
from an evolutionary standpoint for the

705
00:32:00,129 --> 00:31:58,489
galaxies standpoint whereas it's the

706
00:32:03,939 --> 00:32:00,139
most massive stars the ones that live

707
00:32:06,249 --> 00:32:03,949
live live fast and die young that that

708
00:32:09,009 --> 00:32:06,259
create most of the energising of the

709
00:32:11,079 --> 00:32:09,019
interstellar gas forcing new star

710
00:32:13,209 --> 00:32:11,089
formation to happen as those shockwaves

711
00:32:14,859 --> 00:32:13,219
from the supernova impact clouds of gas

712
00:32:16,390 --> 00:32:14,869
and dust and make them collapse and so

713
00:32:18,310 --> 00:32:16,400

forth so I'll

714

00:32:21,280 --> 00:32:18,320

probably mostly concentrate on the more

715

00:32:23,080 --> 00:32:21,290

massive stars and supernova remnants

716

00:32:27,370 --> 00:32:23,090

that come from those massive stars as we

717

00:32:29,740 --> 00:32:27,380

go on through the talk the other piece

718

00:32:32,080 --> 00:32:29,750

of context I wanted to give you is we

719

00:32:33,640 --> 00:32:32,090

all love these beautiful color pictures

720

00:32:36,160 --> 00:32:33,650

that we get out of Hubble and out of

721

00:32:38,050 --> 00:32:36,170

other missions as well and I wanted to

722

00:32:40,420 --> 00:32:38,060

put that in context a little bit as well

723

00:32:42,580 --> 00:32:40,430

this is the Kepler supernova remnant it

724

00:32:46,000 --> 00:32:42,590

came from an explosion that Johannes

725

00:32:47,890 --> 00:32:46,010

Kepler observed in 1604 one of my

726

00:32:50,140 --> 00:32:47,900

favorite objects here and what we're

727

00:32:52,810 --> 00:32:50,150

looking at in this color picture is

728

00:32:55,210 --> 00:32:52,820

actually a combination of Chandra x-ray

729

00:32:57,340 --> 00:32:55,220

data two different colors here blue in

730

00:32:59,200 --> 00:32:57,350

the green in this picture this is harder

731

00:33:01,720 --> 00:32:59,210

x-rays that show you the kind of the

732

00:33:04,750 --> 00:33:01,730

outer rim is the brightest that's the

733

00:33:06,760 --> 00:33:04,760

shock wave and the hardest x-rays the

734

00:33:09,370 --> 00:33:06,770

green is a little bit interior to that

735

00:33:12,820 --> 00:33:09,380

that is the actual ejecta the star stuff

736

00:33:15,280 --> 00:33:12,830

from the supernova that exploded okay

737

00:33:17,260 --> 00:33:15,290

the yellow which I'll show in more

738

00:33:19,210 --> 00:33:17,270

detail on the other side here but you

739

00:33:20,980 --> 00:33:19,220

see the yellow in here is the densest

740

00:33:22,810 --> 00:33:20,990

clumps of stuff that's what Hubble sees

741

00:33:25,390 --> 00:33:22,820

is the really dead stuff in the optical

742

00:33:26,920 --> 00:33:25,400

so the yellow is Hubble and this is one

743

00:33:28,870 --> 00:33:26,930

wavelength of infrared emission from the

744

00:33:31,690 --> 00:33:28,880

Spitzer Space Telescope it's actually

745

00:33:33,580 --> 00:33:31,700

showing us warm dust that is heated by

746

00:33:35,800 --> 00:33:33,590

the shockwave and you see how it's

747

00:33:38,680 --> 00:33:35,810

one-sided how one side of this structure

748

00:33:41,680 --> 00:33:38,690

is really dominant in the heated dust

749

00:33:43,180 --> 00:33:41,690

and that's it turns out putting all this

750

00:33:45,490 --> 00:33:43,190

together like this is telling us that

751
00:33:47,530 --> 00:33:45,500
the shockwave was running up a density

752
00:33:50,410 --> 00:33:47,540
gradient it's denser up there in the

753
00:33:52,060 --> 00:33:50,420
upper right and the dust is denser and

754
00:33:55,170 --> 00:33:52,070
it's getting heated up by the shockwave

755
00:33:57,640 --> 00:33:55,180
is that impinges on that denser material

756
00:33:59,440 --> 00:33:57,650
so again looking at things at different

757
00:34:02,590 --> 00:33:59,450
wavelengths one of the points here is

758
00:34:05,500 --> 00:34:02,600
that supernova remnants observe across

759
00:34:07,330 --> 00:34:05,510
the light spectrum from x-ray all the

760
00:34:08,950 --> 00:34:07,340
way out to radio I don't have radio on

761
00:34:12,370 --> 00:34:08,960
here but they're strong radio sources as

762
00:34:14,590 --> 00:34:12,380
well infrared optical ultraviolet across

763
00:34:15,909 --> 00:34:14,600

the spectrum they're very multi

764

00:34:18,250 --> 00:34:15,919

wavelength and so that's right I'm

765

00:34:21,159 --> 00:34:18,260

taking a multi wavelength approach to

766

00:34:22,480 --> 00:34:21,169

look at this galaxy m83 we have to look

767

00:34:24,040 --> 00:34:22,490

at different wavelengths to find the

768

00:34:25,450 --> 00:34:24,050

ones that are bright and x-ray versus

769

00:34:28,629 --> 00:34:25,460

the ones that are bright optically and

770

00:34:32,300 --> 00:34:30,680

okay so when we make these color

771

00:34:33,919 --> 00:34:32,310

pictures like it's kind of I kind knows

772

00:34:37,970 --> 00:34:33,929

this but I just wanted to point out that

773

00:34:40,610 --> 00:34:37,980

you know if I make one one image in red

774

00:34:42,980 --> 00:34:40,620

one image in green and one image in blue

775

00:34:44,629 --> 00:34:42,990

then where things are bright in more

776
00:34:47,119 --> 00:34:44,639
than one band you get different colors

777
00:34:49,310 --> 00:34:47,129
okay if it's bright and the blue and the

778
00:34:51,379 --> 00:34:49,320
red you get this kind of pinky magenta

779
00:34:53,419 --> 00:34:51,389
color if you if it's bright and blue and

780
00:34:55,220 --> 00:34:53,429
green you get that cyan color and if

781
00:34:57,290 --> 00:34:55,230
it's bright in red and green you get

782
00:34:59,630 --> 00:34:57,300
yellow and so if I make a color image

783
00:35:01,430 --> 00:34:59,640
out of three different images of

784
00:35:03,980 --> 00:35:01,440
different wavelengths of light or

785
00:35:05,390 --> 00:35:03,990
different data from different

786
00:35:08,240 --> 00:35:05,400
instruments like we just looked at from

787
00:35:10,070 --> 00:35:08,250
Chandra and from Hubble and so forth you

788
00:35:11,420 --> 00:35:10,080

can compare the similarities and

789

00:35:12,890 --> 00:35:11,430

differences by looking at the colors

790

00:35:14,450 --> 00:35:12,900

where they're both bright

791

00:35:16,040 --> 00:35:14,460

that's one of the tricks we play and

792

00:35:18,140 --> 00:35:16,050

then over here I just show that

793

00:35:19,550 --> 00:35:18,150

basically it's not an on/off thing like

794

00:35:21,560 --> 00:35:19,560

this it's basically there's all kinds of

795

00:35:23,650 --> 00:35:21,570

gradation in the color that you get as

796

00:35:26,030 --> 00:35:23,660

you combine those in different amounts

797

00:35:28,700 --> 00:35:26,040

so as we make color pictures we can

798

00:35:30,380 --> 00:35:28,710

actually use that to diagnose what's

799

00:35:32,000 --> 00:35:30,390

going on if we understand what the

800

00:35:36,620 --> 00:35:32,010

images are that went into the the

801
00:35:38,270 --> 00:35:36,630
pictures okay so one of the problems

802
00:35:40,250 --> 00:35:38,280
that we have just looking locally you

803
00:35:42,380 --> 00:35:40,260
say why don't we look at m83 look you

804
00:35:44,180 --> 00:35:42,390
know 15 million light years away in

805
00:35:45,410 --> 00:35:44,190
another galaxy to find supernovae in

806
00:35:47,600 --> 00:35:45,420
this we've got ones in our own galaxy

807
00:35:50,420 --> 00:35:47,610
that we can look at in great detail and

808
00:35:52,760 --> 00:35:50,430
indeed we do but part of the problem is

809
00:35:55,460 --> 00:35:52,770
that we have very few of these very

810
00:35:57,080 --> 00:35:55,470
young objects that we can look at and

811
00:35:59,090 --> 00:35:57,090
understand and kind of put together the

812
00:36:00,980 --> 00:35:59,100
big picture of what's going on this is

813
00:36:02,690 --> 00:36:00,990

the Crab Nebula with Hubble three

814

00:36:05,210 --> 00:36:02,700

different wavelengths of Hubble light

815

00:36:07,520 --> 00:36:05,220

put together into a couple color picture

816

00:36:10,430 --> 00:36:07,530

here and this is the Cassiopeia a

817

00:36:13,160 --> 00:36:10,440

supernova remnant which is a much more

818

00:36:16,280 --> 00:36:13,170

massive star that blew up in our galaxy

819

00:36:17,900 --> 00:36:16,290

and this is the same color coding that I

820

00:36:20,030 --> 00:36:17,910

had on that Kepler picture a minute ago

821

00:36:22,820 --> 00:36:20,040

where the yellow is a Hubble and the red

822

00:36:24,800 --> 00:36:22,830

is the infrared band and the blue and

823

00:36:27,290 --> 00:36:24,810

the green are the x-ray and you can see

824

00:36:28,880 --> 00:36:27,300

how they all mess up there and this in

825

00:36:32,300 --> 00:36:28,890

this explosion which is expanding at

826

00:36:33,980 --> 00:36:32,310

very high velocities even some 300 400

827

00:36:35,750 --> 00:36:33,990

years after the explosion still

828

00:36:37,790 --> 00:36:35,760

expanding at ten or twelve thousand

829

00:36:41,210 --> 00:36:37,800

kilometers per second interestingly

830

00:36:41,450 --> 00:36:41,220

enough the Crab Nebula almost a thousand

831

00:36:44,030 --> 00:36:41,460

years

832

00:36:45,920 --> 00:36:44,040

old and it's only expanding at 1,800

833

00:36:48,950 --> 00:36:45,930

kilometers per second and we think it

834

00:36:51,710 --> 00:36:48,960

came from a much lower mass star so

835

00:36:53,329 --> 00:36:51,720

let's say we have half a dozen of these

836

00:36:55,250 --> 00:36:53,339

kinds of objects or something like that

837

00:36:58,579 --> 00:36:55,260

to look at we've got the mass varying

838

00:37:00,470 --> 00:36:58,589

we've got the expansion the age is

839

00:37:02,240 --> 00:37:00,480

different the expansion velocities are

840

00:37:03,800 --> 00:37:02,250

different how do we take all these

841

00:37:05,450 --> 00:37:03,810

pieces of information and put it

842

00:37:07,849 --> 00:37:05,460

together into a picture when we have so

843

00:37:10,849 --> 00:37:07,859

few objects to kind of put together and

844

00:37:14,359 --> 00:37:10,859

make that picture and just as a another

845

00:37:16,670 --> 00:37:14,369

sign of how crazy these are this 8 or 10

846

00:37:18,859 --> 00:37:16,680

solar mass star we know produced this

847

00:37:20,720 --> 00:37:18,869

inquiry this crazy Crab Nebula pulsar

848

00:37:22,220 --> 00:37:20,730

down here in the center of the object

849

00:37:24,500 --> 00:37:22,230

that is actually what's energizing and

850

00:37:27,589 --> 00:37:24,510

actually accelerating the expansion of

851
00:37:30,349 --> 00:37:27,599
the material from the explosion whereas

852
00:37:32,180 --> 00:37:30,359
this big monster 25 solar mass star that

853
00:37:33,920 --> 00:37:32,190
blew up here made this wimpy little

854
00:37:36,680 --> 00:37:33,930
neutron star down here that we don't

855
00:37:38,540 --> 00:37:36,690
even see any pulses from there so there

856
00:37:40,579 --> 00:37:38,550
is a stellar remnant left behind from

857
00:37:43,640 --> 00:37:40,589
the explosion but it's not anything that

858
00:37:47,180 --> 00:37:43,650
would knock your socks off like the Crab

859
00:37:50,990 --> 00:37:47,190
Nebula pulsar so very few objects to

860
00:37:53,450 --> 00:37:51,000
understand the parameter space and many

861
00:37:55,640 --> 00:37:53,460
things changing it makes it hard and so

862
00:37:57,349 --> 00:37:55,650
we'd like to find a lot of these young

863
00:37:58,609 --> 00:37:57,359

remnants and look at them especially if

864

00:38:00,440 --> 00:37:58,619

they were all at the same distance you

865

00:38:02,420 --> 00:38:00,450

take the distance difference out of it

866

00:38:03,650 --> 00:38:02,430

you can look at that sample of objects

867

00:38:06,980 --> 00:38:03,660

that are all at the same distance and

868

00:38:09,410 --> 00:38:06,990

understand systematically what's going

869

00:38:10,700 --> 00:38:09,420

on with massive star supernova remnants

870

00:38:15,920 --> 00:38:10,710

so that was one of the motivations for

871

00:38:17,540 --> 00:38:15,930

going to how to m83 alright so I'm gonna

872

00:38:18,680 --> 00:38:17,550

leave the Crab Nebula behind now that

873

00:38:20,359 --> 00:38:18,690

was kind of at the lower end of a

874

00:38:22,609 --> 00:38:20,369

massive star these are all these are

875

00:38:25,339 --> 00:38:22,619

three supernova remnants of we think

876

00:38:27,589 --> 00:38:25,349

very massive stars here's Cassie again

877

00:38:30,589 --> 00:38:27,599

in our galaxy and below below here I

878

00:38:33,050 --> 00:38:30,599

just have a blow-up of some Hubble data

879

00:38:36,020 --> 00:38:33,060

that that shows some of the detail in

880

00:38:38,120 --> 00:38:36,030

this stuff this is star stuff this is

881

00:38:40,550 --> 00:38:38,130

the guts of the massive star that blew

882

00:38:42,349 --> 00:38:40,560

up and the material is still in the

883

00:38:45,260 --> 00:38:42,359

process of flying out into space at very

884

00:38:46,820 --> 00:38:45,270

high velocities and eventually it will

885

00:38:49,160 --> 00:38:46,830

blend back into the interstellar medium

886

00:38:52,209 --> 00:38:49,170

and maybe participate in the next round

887

00:38:55,689 --> 00:38:52,219

of star formation that will have

888

00:38:57,849 --> 00:38:55,699

abundances then the current ones do okay

889

00:39:00,279 --> 00:38:57,859

this is an object in a small magellanic

890

00:39:03,160 --> 00:39:00,289

cloud that is very similar to this only

891

00:39:05,589 --> 00:39:03,170

it's larger it's older but the only

892

00:39:07,900 --> 00:39:05,599

thing we see with Hubble this blue stuff

893

00:39:09,309 --> 00:39:07,910

that you see in that picture is almost

894

00:39:11,529 --> 00:39:09,319

pure oxygen

895

00:39:14,109 --> 00:39:11,539

it's from the layer of the star that

896

00:39:15,249 --> 00:39:14,119

produced oxygen there if you took a

897

00:39:16,749 --> 00:39:15,259

spectrum of that you would see there

898

00:39:19,449 --> 00:39:16,759

would be some neon and some other things

899

00:39:22,150 --> 00:39:19,459

in there but as you see no hydrogen it's

900

00:39:24,969 --> 00:39:22,160

all the star stuff that's flying out

901
00:39:26,979 --> 00:39:24,979
into space this object is in the Large

902
00:39:31,809 --> 00:39:26,989
Magellanic Cloud or neighboring galaxies

903
00:39:33,519 --> 00:39:31,819
of ours and it is larger it has a kind

904
00:39:35,229 --> 00:39:33,529
of an outer shell here that's starting

905
00:39:36,519 --> 00:39:35,239
to form from the blast wave going out of

906
00:39:38,439 --> 00:39:36,529
the space and starting to sweep up

907
00:39:40,809 --> 00:39:38,449
surrounding material so you're getting

908
00:39:43,359 --> 00:39:40,819
that outer shell starting to form but

909
00:39:46,420 --> 00:39:43,369
down in the center here this blue and

910
00:39:47,920 --> 00:39:46,430
green stuff in this picture is this kind

911
00:39:50,499 --> 00:39:47,930
of stuff it's the star stuff still

912
00:39:53,890 --> 00:39:50,509
visible even though it's a much much

913
00:39:55,989 --> 00:39:53,900

older object and to put those three in a

914

00:39:58,329 --> 00:39:55,999

little more of a context for you and in

915

00:40:01,479 --> 00:39:58,339

this graph I try to graphic I try to

916

00:40:05,109 --> 00:40:01,489

show you their relative sizes to give

917

00:40:07,239 --> 00:40:05,119

you a little sense so Cassie 340 years

918

00:40:10,269 --> 00:40:07,249

since the explosion 18 light-years in

919

00:40:13,599 --> 00:40:10,279

size yellow 102 this one with the

920

00:40:15,969 --> 00:40:13,609

phonebook name is about 1200 years old

921

00:40:18,339 --> 00:40:15,979

and is a little over 40 kilometres per

922

00:40:21,009 --> 00:40:18,349

second this is expanding at say 10,000

923

00:40:22,959 --> 00:40:21,019

this is 2,000 and over here the outer

924

00:40:25,479 --> 00:40:22,969

structure is not expanding rapidly but

925

00:40:27,819 --> 00:40:25,489

that green stuff the oxygen stuff in

926
00:40:30,609 --> 00:40:27,829
there is still expanding and a thousand

927
00:40:33,880 --> 00:40:30,619
kilometers per second even some 3,000

928
00:40:35,739 --> 00:40:33,890
years or more after the explosion and so

929
00:40:37,959 --> 00:40:35,749
if we wanted to find this kind of object

930
00:40:39,910 --> 00:40:37,969
in other galaxies we would want to look

931
00:40:41,859 --> 00:40:39,920
for high velocities and we would want to

932
00:40:44,709 --> 00:40:41,869
look for these funny abundances compared

933
00:40:47,589 --> 00:40:44,719
to the surrounding gas and that's one of

934
00:40:49,299 --> 00:40:47,599
the ways we try to find them I'm just

935
00:40:52,479 --> 00:40:49,309
taking that one step further I like to

936
00:40:54,249 --> 00:40:52,489
make this point because you know this is

937
00:40:56,109 --> 00:40:54,259
thought of as a young object the veil

938
00:40:57,549 --> 00:40:56,119

nebula the Cygnus loop is thought of

939

00:40:59,079 --> 00:40:57,559

it's kind of an old or a middle-aged

940

00:41:01,419 --> 00:40:59,089

object and yet sighs this is the

941

00:41:03,959 --> 00:41:01,429

relative sizes again not too different

942

00:41:05,230 --> 00:41:03,969

88 light years versus 82 light years

943

00:41:07,630 --> 00:41:05,240

inside

944

00:41:09,970 --> 00:41:07,640

again this outer shell is thought to be

945

00:41:12,430 --> 00:41:09,980

sort of the wall of a cavity that was

946

00:41:14,800 --> 00:41:12,440

blown by the wind from the star before

947

00:41:17,080 --> 00:41:14,810

it blew up so there's a cavity that it's

948

00:41:18,460 --> 00:41:17,090

expanding into that's the same model we

949

00:41:20,350 --> 00:41:18,470

have for the Cygnus loop this bright

950

00:41:21,790 --> 00:41:20,360

emission on the outside edges where the

951
00:41:24,820 --> 00:41:21,800
shock wave is finally starting to hit

952
00:41:26,230 --> 00:41:24,830
the outside edges of a cavity so the two

953
00:41:28,060 --> 00:41:26,240
stars the blue up here could be very

954
00:41:31,360 --> 00:41:28,070
similar to each other and yet we don't

955
00:41:33,520 --> 00:41:31,370
see the oxygen-rich the ejecta in this

956
00:41:35,380 --> 00:41:33,530
one they're starting to tease it out of

957
00:41:36,640 --> 00:41:35,390
very deep x-ray observations in the

958
00:41:38,320 --> 00:41:36,650
Cygnus oh they're starting to see some

959
00:41:40,690 --> 00:41:38,330
of that enhancement but most of that

960
00:41:43,570 --> 00:41:40,700
stuff is blended back in or faded away

961
00:41:45,250 --> 00:41:43,580
at this point and so this object is on

962
00:41:46,450 --> 00:41:45,260
its way to becoming something like the

963
00:41:50,110 --> 00:41:46,460

Cygnus of when they're about the same

964

00:41:51,340 --> 00:41:50,120

the same size this has nothing to do

965

00:41:52,450 --> 00:41:51,350

with the rest of the talk but I had to

966

00:41:55,210 --> 00:41:52,460

throw it in here you see this little

967

00:41:57,070 --> 00:41:55,220

white box on the side there was this

968

00:41:59,260 --> 00:41:57,080

wonderful picture of the Cygnus loop

969

00:42:02,140 --> 00:41:59,270

just that tiny little section that was

970

00:42:03,940 --> 00:42:02,150

released last year that makes the point

971

00:42:05,470 --> 00:42:03,950

also that you know you use the different

972

00:42:08,260 --> 00:42:05,480

colors to represent things so we've got

973

00:42:11,260 --> 00:42:08,270

an oxygen hydrogen and a sulphur band in

974

00:42:12,640 --> 00:42:11,270

blue red and green and then you can see

975

00:42:15,580 --> 00:42:12,650

how the colors are mixing together you

976
00:42:17,650 --> 00:42:15,590
get the yellows which means that H alpha

977
00:42:19,150 --> 00:42:17,660
and the software too are bright you see

978
00:42:21,550 --> 00:42:19,160
the places where the blue is dominant

979
00:42:23,020 --> 00:42:21,560
where the oxygen high ionization oxygen

980
00:42:24,940 --> 00:42:23,030
is dominant and so forth so you can

981
00:42:28,260 --> 00:42:24,950
again you get a sense for what how you

982
00:42:30,580 --> 00:42:28,270
get diagnostic power out of the color

983
00:42:32,980 --> 00:42:30,590
images if you understand something about

984
00:42:35,620 --> 00:42:32,990
what's going into the picture but that's

985
00:42:38,260 --> 00:42:35,630
just a spectacular picture this cloud up

986
00:42:39,610 --> 00:42:38,270
here is probably unrelated directly to

987
00:42:41,110 --> 00:42:39,620
this it's either the foreground or

988
00:42:43,120 --> 00:42:41,120

background and just happens to be in the

989

00:42:46,540 --> 00:42:43,130

frame out here and there's a one light

990

00:42:48,250 --> 00:42:46,550

one light-year bar across there so so

991

00:42:50,170 --> 00:42:48,260

the whole object of course is much much

992

00:42:52,240 --> 00:42:50,180

much much larger we're looking at a tiny

993

00:42:57,520 --> 00:42:52,250

little piece of it and this this Hubble

994

00:43:00,430 --> 00:42:57,530

picture this picture is 18 orbits of

995

00:43:02,200 --> 00:43:00,440

Hubble data about a hundred separate

996

00:43:03,970 --> 00:43:02,210

images and those different filters all

997

00:43:06,900 --> 00:43:03,980

align then put together this was

998

00:43:09,580 --> 00:43:06,910

actually three by two

999

00:43:11,170 --> 00:43:09,590

wipsy three fields of view for the

1000

00:43:13,720 --> 00:43:11,180

Hubble telescope so this has been all

1001
00:43:15,370 --> 00:43:13,730
stitched together four six six fields of

1002
00:43:17,240 --> 00:43:15,380
the of the wide field camera to put

1003
00:43:20,120 --> 00:43:17,250
together this picture of that one

1004
00:43:22,730 --> 00:43:20,130
piece of the cygnets loop Hubble's job

1005
00:43:24,920 --> 00:43:22,740
is to look at small areas of the sky in

1006
00:43:29,300 --> 00:43:24,930
very great detail that's that's this

1007
00:43:31,490 --> 00:43:29,310
reason for existence basically okay well

1008
00:43:33,050 --> 00:43:31,500
we're almost to m83 I just want to kind

1009
00:43:34,850 --> 00:43:33,060
of give you the big picture here first I

1010
00:43:37,550 --> 00:43:34,860
mean the idea remember is that we want

1011
00:43:40,010 --> 00:43:37,560
to understand the star formation

1012
00:43:42,500 --> 00:43:40,020
processes and the whole evolution of

1013
00:43:44,840 --> 00:43:42,510

stars and we want to do that for the

1014

00:43:47,090 --> 00:43:44,850

four galaxies in the local universe it

1015

00:43:48,950 --> 00:43:47,100

turns out m83 is a prime testing ground

1016

00:43:51,140 --> 00:43:48,960

for doing this because you want to

1017

00:43:52,880 --> 00:43:51,150

understand by comparing local galaxies

1018

00:43:55,220 --> 00:43:52,890

to more distant galaxies whether these

1019

00:43:57,260 --> 00:43:55,230

processes that that that guide this

1020

00:44:00,170 --> 00:43:57,270

stuff are universal processes or whether

1021

00:44:01,790 --> 00:44:00,180

there are differences and the part that

1022

00:44:03,710 --> 00:44:01,800

I'm really most interested in most

1023

00:44:05,420 --> 00:44:03,720

involved in is in finding the supernova

1024

00:44:09,500 --> 00:44:05,430

remnants which is just the one part of

1025

00:44:10,400 --> 00:44:09,510

this bigger picture so most of the rest

1026

00:44:11,990 --> 00:44:10,410

of this I'm going to be talking about

1027

00:44:13,910 --> 00:44:12,000

trying to find the supernova remnants

1028

00:44:15,350 --> 00:44:13,920

and telling you how we do that so here's

1029

00:44:18,200 --> 00:44:15,360

a ground-based picture very nice

1030

00:44:20,390 --> 00:44:18,210

ground-based picture of m83 about 15

1031

00:44:22,670 --> 00:44:20,400

million light years away one arcsecond

1032

00:44:24,830 --> 00:44:22,680

is about 72 light years and one

1033

00:44:26,300 --> 00:44:24,840

arcsecond is kind of as you a lot of

1034

00:44:27,950 --> 00:44:26,310

amateur astronomers out here I presume

1035

00:44:29,570 --> 00:44:27,960

were people that know that's basically

1036

00:44:31,430 --> 00:44:29,580

kind of what you get from ground-based

1037

00:44:33,260 --> 00:44:31,440

observations is about one arc second or

1038

00:44:35,000 --> 00:44:33,270

sometimes a little bit worse sometimes a

1039

00:44:36,560 --> 00:44:35,010

little bit better but of course Hubble

1040

00:44:38,090 --> 00:44:36,570

can do about twenty times better than

1041

00:44:40,490 --> 00:44:38,100

that so we're getting down to just a few

1042

00:44:42,260 --> 00:44:40,500

light years type resolution with Hubble

1043

00:44:44,480 --> 00:44:42,270

pictures when we look at this thing

1044

00:44:46,250 --> 00:44:44,490

that's 15 million light years away and

1045

00:44:48,200 --> 00:44:46,260

we can still resolve things that's just

1046

00:44:51,410 --> 00:44:48,210

a few light-years in size that's pretty

1047

00:44:53,030 --> 00:44:51,420

spectacular okay it's a called a barred

1048

00:44:54,650 --> 00:44:53,040

spiral galaxy there's certainly other

1049

00:44:56,150 --> 00:44:54,660

galaxies and have more prominent bars

1050

00:44:58,220 --> 00:44:56,160

but you can see it's kind of extended

1051
00:45:01,130 --> 00:44:58,230
here it's got this very bright nucleus

1052
00:45:04,010 --> 00:45:01,140
where star formation is just happening

1053
00:45:06,230 --> 00:45:04,020
at a tremendous burst but you see also a

1054
00:45:08,210 --> 00:45:06,240
lot of these h2 regions around out

1055
00:45:10,820 --> 00:45:08,220
through the spiral arms where where star

1056
00:45:12,110 --> 00:45:10,830
formation is happening it turns out this

1057
00:45:14,120 --> 00:45:12,120
galaxy is a great place to look for

1058
00:45:17,180 --> 00:45:14,130
supernova remnants because it's produced

1059
00:45:19,430 --> 00:45:17,190
a ton of supernovae we've actually seen

1060
00:45:22,390 --> 00:45:19,440
over the last hundred years six

1061
00:45:25,100 --> 00:45:22,400
supernovae in m83

1062
00:45:27,710 --> 00:45:25,110
we found another object that I'll

1063
00:45:29,300 --> 00:45:27,720

mention briefly as we go along that has

1064

00:45:30,589 --> 00:45:29,310

to be less than 100 years old that was

1065

00:45:33,259 --> 00:45:30,599

probably a supernova that

1066

00:45:35,059 --> 00:45:33,269

did not see maybe it happened when

1067

00:45:36,890 --> 00:45:35,069

anybody through is behind the Sun we

1068

00:45:38,269 --> 00:45:36,900

don't know exactly but anyway there's

1069

00:45:39,559 --> 00:45:38,279

another one that's young that's so

1070

00:45:42,920 --> 00:45:39,569

probably seven of them in the last

1071

00:45:47,569 --> 00:45:42,930

century interestingly enough none since

1072

00:45:49,460 --> 00:45:47,579

1983 we are do we are do we had seven of

1073

00:45:51,140 --> 00:45:49,470

them in the first part of the 20th

1074

00:45:52,880 --> 00:45:51,150

century and now none since thinking 83

1075

00:45:55,329 --> 00:45:52,890

so we ought to be seeing some super

1076

00:45:57,710 --> 00:45:55,339

novae coming for maybe three pretty soon

1077

00:45:59,509 --> 00:45:57,720

and just for context again this is a

1078

00:46:00,979 --> 00:45:59,519

quarter of a degree field of view that I

1079

00:46:02,539 --> 00:46:00,989

was showing here of course the full moon

1080

00:46:05,989 --> 00:46:02,549

is about a half a degree across so it's

1081

00:46:07,279 --> 00:46:05,999

a sizable galaxy on the sky but

1082

00:46:09,440 --> 00:46:07,289

interestingly enough if you put this

1083

00:46:11,390 --> 00:46:09,450

where the Milky Way is this this whole

1084

00:46:13,219 --> 00:46:11,400

thing is you would like put two

1085

00:46:14,660 --> 00:46:13,229

side-by-side and two up and down that's

1086

00:46:16,400 --> 00:46:14,670

gonna be about the size of the Milky Way

1087

00:46:18,859 --> 00:46:16,410

galaxy so it's actually a relatively

1088

00:46:19,579 --> 00:46:18,869

small spiral galaxy compared to our

1089

00:46:24,620 --> 00:46:19,589

Milky Way

1090

00:46:26,120 --> 00:46:24,630

I mentioned that it had six or possibly

1091

00:46:28,819 --> 00:46:26,130

seven supernovae here's where they are

1092

00:46:30,349 --> 00:46:28,829

located across the galaxy some of them

1093

00:46:33,440 --> 00:46:30,359

are very close to star forming regions

1094

00:46:35,390 --> 00:46:33,450

some of them are are not one is right

1095

00:46:36,890 --> 00:46:35,400

down here in the in this bright nucleus

1096

00:46:40,249 --> 00:46:36,900

where there's tremendous activity going

1097

00:46:41,900 --> 00:46:40,259

on near star formation again your star

1098

00:46:43,940 --> 00:46:41,910

formation up here I'll talk about this

1099

00:46:45,769 --> 00:46:43,950

object and this object this is the one

1100

00:46:48,559 --> 00:46:45,779

that I think we found that has to be

1101

00:46:50,950 --> 00:46:48,569

young but the supernova was not seen but

1102

00:46:53,809 --> 00:46:50,960

the point is with this many supernovae

1103

00:46:55,370 --> 00:46:53,819

less than a hundred years old if we want

1104

00:46:58,099 --> 00:46:55,380

to take what you want to take a thousand

1105

00:47:00,140 --> 00:46:58,109

or 1500 years as a young supernova

1106

00:47:03,170 --> 00:47:00,150

remnant there ought to be 6070 maybe

1107

00:47:05,509 --> 00:47:03,180

even a hundred of these young ejecta

1108

00:47:07,279 --> 00:47:05,519

dominated supernova remnants in this

1109

00:47:08,930 --> 00:47:07,289

galaxy and so that's why one of the

1110

00:47:10,279 --> 00:47:08,940

reasons we wanted to look here we also

1111

00:47:12,769 --> 00:47:10,289

wanted to find the normal supernova

1112

00:47:14,779 --> 00:47:12,779

remnants like the Cygnus loop and so the

1113

00:47:18,049 --> 00:47:14,789

search actually looked for both of those

1114

00:47:20,059 --> 00:47:18,059

things so just very briefly we used a

1115

00:47:22,519 --> 00:47:20,069

large ground-based telescope here at Las

1116

00:47:25,299 --> 00:47:22,529

Campanas Observatory for a ground-based

1117

00:47:28,160 --> 00:47:25,309

search and we actually found 225

1118

00:47:30,319 --> 00:47:28,170

supernova remnant candidates from that

1119

00:47:32,329 --> 00:47:30,329

ground-based search so the question is

1120

00:47:33,829 --> 00:47:32,339

why do we need Hubble well we could find

1121

00:47:35,959 --> 00:47:33,839

them but we couldn't measure their sizes

1122

00:47:38,509 --> 00:47:35,969

from the ground even with very excellent

1123

00:47:40,190 --> 00:47:38,519

ground-based data most of the objects we

1124

00:47:41,870 --> 00:47:40,200

wanted to get you know see if they had

1125

00:47:44,300 --> 00:47:41,880

shells or if they were very small

1126
00:47:46,010 --> 00:47:44,310
objects or whatever we couldn't do with

1127
00:47:47,750 --> 00:47:46,020
with Magellan and so we had to do that

1128
00:47:50,560 --> 00:47:47,760
with with Hubble and so down here is the

1129
00:47:53,030 --> 00:47:50,570
Hubble part of the project we also have

1130
00:47:55,640 --> 00:47:53,040
730 Killa seconds that's a lot of time

1131
00:47:57,350 --> 00:47:55,650
on the Chandra x-ray Observatory to take

1132
00:47:59,510 --> 00:47:57,360
a very deep x-ray picture of this galaxy

1133
00:48:01,550 --> 00:47:59,520
we found four hundred and forty point

1134
00:48:02,990 --> 00:48:01,560
sources and lots of the few submission

1135
00:48:04,220 --> 00:48:03,000
I'll show you that and then there are

1136
00:48:06,460 --> 00:48:04,230
other datasets that we're working on

1137
00:48:08,630 --> 00:48:06,470
including radio again multi-wavelength

1138
00:48:11,330 --> 00:48:08,640

spectroscopic follow up and I'll show

1139

00:48:13,400 --> 00:48:11,340

you a couple of spectra from that as we

1140

00:48:17,240 --> 00:48:13,410

go along but I basically won't talk

1141

00:48:20,750 --> 00:48:17,250

about those very much that part of it so

1142

00:48:24,350 --> 00:48:20,760

there is I showed you here the optical

1143

00:48:26,870 --> 00:48:24,360

picture of the galaxy right and here is

1144

00:48:28,760 --> 00:48:26,880

this deep x-ray picture of the galaxy -

1145

00:48:30,380 --> 00:48:28,770

approximately the same scale you can

1146

00:48:32,780 --> 00:48:30,390

even kind of see the spiral arms and

1147

00:48:36,460 --> 00:48:32,790

that red diffuse gas there you see this

1148

00:48:40,130 --> 00:48:36,470

incredible x-ray bright region

1149

00:48:42,440 --> 00:48:40,140

associated with the starburst nucleus in

1150

00:48:44,540 --> 00:48:42,450

there and all these little point sources

1151
00:48:46,760 --> 00:48:44,550
and vast majority of those point sources

1152
00:48:49,310 --> 00:48:46,770
are actually in n83 a lot of the

1153
00:48:52,220 --> 00:48:49,320
brighter whitish looking ones are x-ray

1154
00:48:53,840 --> 00:48:52,230
binary stars and you can see that

1155
00:48:55,130 --> 00:48:53,850
because some of those sources vary over

1156
00:48:57,350 --> 00:48:55,140
time and whatnot because they're in

1157
00:48:58,640 --> 00:48:57,360
binary orbits and the things that don't

1158
00:49:00,890 --> 00:48:58,650
look too impressive on here a lot of

1159
00:49:03,140 --> 00:49:00,900
these little little red red dots or

1160
00:49:05,450 --> 00:49:03,150
yellow dots and places are oftentimes

1161
00:49:07,280 --> 00:49:05,460
are associated with optical supernova

1162
00:49:09,320 --> 00:49:07,290
remnants so we have a lot of supernovae

1163
00:49:11,900 --> 00:49:09,330

that show up the color coding here goes

1164

00:49:14,000 --> 00:49:11,910

from relatively low energy x-rays in the

1165

00:49:16,520 --> 00:49:14,010

red up to the higher and their energy

1166

00:49:18,950 --> 00:49:16,530

x-rays in the blue and so this diffuse

1167

00:49:20,990 --> 00:49:18,960

gas this is the brightest diffuse x-ray

1168

00:49:23,270 --> 00:49:21,000

emission that we have seen in any spiral

1169

00:49:24,440 --> 00:49:23,280

galaxy by the way so if it doesn't look

1170

00:49:26,360 --> 00:49:24,450

too impressive to you you should see

1171

00:49:27,110 --> 00:49:26,370

some of the other galaxies this looks

1172

00:49:29,870 --> 00:49:27,120

pretty good

1173

00:49:33,080 --> 00:49:29,880

and just that tells us that there is hot

1174

00:49:35,270 --> 00:49:33,090

low-density gas permeating the spiral

1175

00:49:38,270 --> 00:49:35,280

arms of this galaxy and that has been

1176
00:49:40,580 --> 00:49:38,280
energized by the stellar formation the

1177
00:49:43,310 --> 00:49:40,590
winds from the stars and the supernova

1178
00:49:45,440 --> 00:49:43,320
explosions over time have energized the

1179
00:49:48,550 --> 00:49:45,450
interstellar medium of this galaxy and

1180
00:49:53,060 --> 00:49:48,560
we get this incredible bright diffuse

1181
00:49:54,890 --> 00:49:53,070
emission also just a little blow-up and

1182
00:49:56,870 --> 00:49:54,900
rescaled so that it's not burned out

1183
00:49:57,410 --> 00:49:56,880
this nuclear region has a tremendous

1184
00:50:00,230 --> 00:49:57,420
number of

1185
00:50:01,760 --> 00:50:00,240
sources and the few submission in there

1186
00:50:03,740 --> 00:50:01,770
as well it's a very complicated reason

1187
00:50:05,089 --> 00:50:03,750
some of those again are aligned with

1188
00:50:07,039 --> 00:50:05,099

supernova remnants and other ones that

1189

00:50:09,049 --> 00:50:07,049

are x-ray binaries in that very active

1190

00:50:11,390 --> 00:50:09,059

nucleus but it's so confused in there

1191

00:50:17,120 --> 00:50:11,400

we've mostly set that aside and worked

1192

00:50:19,880 --> 00:50:17,130

on the outer part of the galaxy the big

1193

00:50:21,319 --> 00:50:19,890

picture here is that m83 although it's

1194

00:50:23,150 --> 00:50:21,329

hanging out there looks like a nice big

1195

00:50:26,420 --> 00:50:23,160

bright spiral galaxy all by itself is

1196

00:50:28,190 --> 00:50:26,430

actually much more extended than we give

1197

00:50:29,720 --> 00:50:28,200

it credit for this is the part we've

1198

00:50:32,359 --> 00:50:29,730

been looking at here in the bright part

1199

00:50:34,539 --> 00:50:32,369

this is galaxies ultraviolet images and

1200

00:50:37,339 --> 00:50:34,549

the red and this picture is actually

1201
00:50:39,530 --> 00:50:37,349
radio h1 emission hydrogen emission that

1202
00:50:43,130 --> 00:50:39,540
shows that there is very faint diffuse

1203
00:50:44,839 --> 00:50:43,140
gas way out there and the blue light

1204
00:50:46,640 --> 00:50:44,849
that you see way out here is star

1205
00:50:48,859 --> 00:50:46,650
formation that is actually happening way

1206
00:50:49,490 --> 00:50:48,869
out here away from the bright part of

1207
00:50:51,740 --> 00:50:49,500
the galaxy

1208
00:50:53,329 --> 00:50:51,750
this probably indicates that at some

1209
00:50:55,160 --> 00:50:53,339
point in the not-too-distant past and

1210
00:50:57,260 --> 00:50:55,170
maybe three had an interaction with

1211
00:50:58,910 --> 00:50:57,270
another galaxy and we don't see that

1212
00:51:00,859 --> 00:50:58,920
other galaxy right now but it was enough

1213
00:51:02,990 --> 00:51:00,869

to kind of really disturb the outer

1214

00:51:04,910 --> 00:51:03,000

structure of m83

1215

00:51:08,289 --> 00:51:04,920

and maybe what triggered this big burst

1216

00:51:10,609 --> 00:51:08,299

of star formation in the galaxy itself

1217

00:51:14,900 --> 00:51:10,619

so that's a much larger scale picture

1218

00:51:16,549 --> 00:51:14,910

than what we were looking at before okay

1219

00:51:19,760 --> 00:51:16,559

so how do we find supernova remnants

1220

00:51:22,400 --> 00:51:19,770

these are spectrum aren't they beautiful

1221

00:51:25,130 --> 00:51:22,410

people like rainbows for spectra for an

1222

00:51:27,710 --> 00:51:25,140

astronomer a graph of intensity versus

1223

00:51:29,390 --> 00:51:27,720

wavelength or versus color blue to red

1224

00:51:30,920 --> 00:51:29,400

in this case these are optical spectra

1225

00:51:33,289 --> 00:51:30,930

intensity

1226
00:51:35,390 --> 00:51:33,299
these are Specter to an astronomer and

1227
00:51:36,890 --> 00:51:35,400
what you see here you see some low-level

1228
00:51:38,900 --> 00:51:36,900
noise going across everything you see

1229
00:51:40,430 --> 00:51:38,910
these spikes that go up this is called

1230
00:51:43,370 --> 00:51:40,440
an emission line spectrum if you look at

1231
00:51:45,319 --> 00:51:43,380
a gas cloud on h2 region or a supernova

1232
00:51:48,319 --> 00:51:45,329
remnant you see emission lines these

1233
00:51:49,880 --> 00:51:48,329
spikes in the spectrum okay and despite

1234
00:51:51,650 --> 00:51:49,890
the relative intensities of the spikes

1235
00:51:53,569 --> 00:51:51,660
change as you look at different objects

1236
00:51:57,170 --> 00:51:53,579
as you look at different kinds of

1237
00:51:59,960 --> 00:51:57,180
objects okay so this is a shock heated

1238
00:52:01,549 --> 00:51:59,970

supernova remnant and what you see is

1239

00:52:04,700 --> 00:52:01,559

that this little line of sulphur out

1240

00:52:06,170 --> 00:52:04,710

here is much stronger relative to the

1241

00:52:09,020 --> 00:52:06,180

hydrogen and there's actually nitrogen

1242

00:52:11,180 --> 00:52:09,030

lines here right next to it the software

1243

00:52:15,319 --> 00:52:11,190

to jumps up the self-reliance jump

1244

00:52:17,150 --> 00:52:15,329

way up the oxygen lines in m83 get very

1245

00:52:20,089 --> 00:52:17,160

strong and many supernovae retinas not

1246

00:52:22,849 --> 00:52:20,099

all of them whereas in the photo star

1247

00:52:26,720 --> 00:52:22,859

light ionized gas the oxygen is very

1248

00:52:28,640 --> 00:52:26,730

weak the sulfur is very weak so knowing

1249

00:52:30,589 --> 00:52:28,650

what the spectra look like now I want to

1250

00:52:32,839 --> 00:52:30,599

say let's go and take pictures and we're

1251
00:52:36,680 --> 00:52:32,849
going to take little filters that just

1252
00:52:37,760 --> 00:52:36,690
get the light from pieces of the

1253
00:52:39,109 --> 00:52:37,770
spectrum and we're going to take

1254
00:52:43,250 --> 00:52:39,119
pictures and then we're going to do an

1255
00:52:44,960 --> 00:52:43,260
RGB of these filters and look for color

1256
00:52:48,800 --> 00:52:44,970
combinations that will tell us which

1257
00:52:49,910 --> 00:52:48,810
objects have strong sulfur - okay and

1258
00:52:52,760 --> 00:52:49,920
that's how we find the supernova

1259
00:52:54,640 --> 00:52:52,770
remnants for the ejecta dominated guys

1260
00:52:56,900 --> 00:52:54,650
it's a little bit different this is a

1261
00:52:59,720 --> 00:52:56,910
spectrum and integrative spectrum of

1262
00:53:01,940 --> 00:52:59,730
Caffe in our galaxy first thing you

1263
00:53:03,890 --> 00:53:01,950

notice of course is the lines are huge

1264

00:53:08,359 --> 00:53:03,900

broad lines that's from that high

1265

00:53:10,579 --> 00:53:08,369

velocity of the ejecta still moving they

1266

00:53:11,960 --> 00:53:10,589

aren't all that broad but but they don't

1267

00:53:13,940 --> 00:53:11,970

have to be that broad for us to see it

1268

00:53:15,559 --> 00:53:13,950

they just have to be broader than then

1269

00:53:16,790 --> 00:53:15,569

we see in these kind of spectra so if

1270

00:53:19,550 --> 00:53:16,800

you saw these things broadened you would

1271

00:53:21,410 --> 00:53:19,560

know that you get high velocity okay I

1272

00:53:23,809 --> 00:53:21,420

say okay so here's my oxygen filter

1273

00:53:26,660 --> 00:53:23,819

here's my H alpha filter there's almost

1274

00:53:28,370 --> 00:53:26,670

no H alpha and the sum of what's there

1275

00:53:30,890 --> 00:53:28,380

is not really related to the KSA and

1276

00:53:33,050 --> 00:53:30,900

then there's a sulphur - filter here so

1277

00:53:35,329 --> 00:53:33,060

this object would look bright and oxygen

1278

00:53:38,000 --> 00:53:35,339

bright and sulfur and almost no H alpha

1279

00:53:39,589 --> 00:53:38,010

or some of the oxygen rich reminisce

1280

00:53:42,500 --> 00:53:39,599

don't have sulphur either so that would

1281

00:53:44,180 --> 00:53:42,510

be right here and not much in either of

1282

00:53:46,400 --> 00:53:44,190

those two bands and so if I found things

1283

00:53:48,800 --> 00:53:46,410

like color coded this blue let's say

1284

00:53:52,220 --> 00:53:48,810

then things that look really blue ought

1285

00:53:54,410 --> 00:53:52,230

to be dominated by the do three emission

1286

00:53:58,910 --> 00:53:54,420

so that's how we find the ejected

1287

00:54:01,130 --> 00:53:58,920

dominated guys where we try to we can

1288

00:54:04,309 --> 00:54:01,140

get confused with just the optical data

1289

00:54:07,490 --> 00:54:04,319

here because planetary nebulae from low

1290

00:54:10,099 --> 00:54:07,500

mass stars also can have strong oxygen 3

1291

00:54:13,599 --> 00:54:10,109

and so the other thing we need is like

1292

00:54:16,490 --> 00:54:13,609

cause we know we have this really strong

1293

00:54:18,500 --> 00:54:16,500

soft x-ray emission as well so we need

1294

00:54:21,079 --> 00:54:18,510

to see something that's bright and

1295

00:54:22,200 --> 00:54:21,089

oxygen and has an Associated x-ray

1296

00:54:23,820 --> 00:54:22,210

source and number

1297

00:54:25,410 --> 00:54:23,830

sure that we've got and ejected

1298

00:54:30,000 --> 00:54:25,420

dominated remnant otherwise it may just

1299

00:54:30,450 --> 00:54:30,010

be a planetary nebula so here's the

1300

00:54:33,510 --> 00:54:30,460

trick

1301

00:54:35,849 --> 00:54:33,520

all right we've h-alpha in red we put

1302

00:54:38,550 --> 00:54:35,859

oxygen three in blue and we put the

1303

00:54:40,170 --> 00:54:38,560

sulfur two in green now the sulfur to

1304

00:54:42,120 --> 00:54:40,180

line is actually in the red part of the

1305

00:54:44,040 --> 00:54:42,130

spectrum but if I did red red and blue

1306

00:54:46,079 --> 00:54:44,050

that I don't have any diagnostic power

1307

00:54:48,480 --> 00:54:46,089

right so I've made the sulfur to green

1308

00:54:50,790 --> 00:54:48,490

and now things that are yellow are

1309

00:54:52,560 --> 00:54:50,800

strong in sulfur Q and H alpha those are

1310

00:54:56,220 --> 00:54:52,570

the normal remnants if I find things

1311

00:54:57,510 --> 00:54:56,230

that are blue or in the cyan I'm pretty

1312

00:54:59,430 --> 00:54:57,520

sure that I've got something that might

1313

00:55:02,849 --> 00:54:59,440

be the ejecta dominated thing and that's

1314

00:55:04,109 --> 00:55:02,859

that's the trick that we play and so

1315

00:55:06,020 --> 00:55:04,119

here's a little example and I'm showing

1316

00:55:08,010 --> 00:55:06,030

you the black and white images

1317

00:55:09,599 --> 00:55:08,020

individually first and then here's the

1318

00:55:12,420 --> 00:55:09,609

color image down here that I'll get to

1319

00:55:14,609 --> 00:55:12,430

in a second so the trick also is that

1320

00:55:16,500 --> 00:55:14,619

when we take images in these emission

1321

00:55:18,630 --> 00:55:16,510

line filters you also get some Starlight

1322

00:55:20,940 --> 00:55:18,640

and so you take a picture that just look

1323

00:55:23,250 --> 00:55:20,950

gets the stars and you scale that and

1324

00:55:25,650 --> 00:55:23,260

subtract it away so you get a pure

1325

00:55:27,089 --> 00:55:25,660

emission line image so here except for

1326

00:55:29,250 --> 00:55:27,099

maybe a few little stellar residuals

1327

00:55:31,950 --> 00:55:29,260

like this you know this is the oxygen 3

1328

00:55:34,410 --> 00:55:31,960

emission only here's the H alpha

1329

00:55:37,020 --> 00:55:34,420

emission only and here's the sulphur 2

1330

00:55:38,820 --> 00:55:37,030

and you can do ratios in black and white

1331

00:55:40,950 --> 00:55:38,830

and actually you can find things right

1332

00:55:42,660 --> 00:55:40,960

like here's the the ratio of software to

1333

00:55:45,329 --> 00:55:42,670

2 H alpha and there's kind of three

1334

00:55:47,339 --> 00:55:45,339

three regions that pop out here and it

1335

00:55:50,339 --> 00:55:47,349

turns out here they are in sulfur 2

1336

00:55:51,720 --> 00:55:50,349

there they are NH alpha this was pretty

1337

00:55:53,130 --> 00:55:51,730

confused but these two you can see

1338

00:55:55,230 --> 00:55:53,140

they're about the same brightness and

1339

00:55:57,510 --> 00:55:55,240

sulfur 2 and H alpha is sure enough they

1340

00:55:59,070 --> 00:55:57,520

pop out in the ratio what's really neat

1341

00:56:02,430 --> 00:55:59,080

here is that even though there's all

1342

00:56:04,589 --> 00:56:02,440

this photo ionized gas around the region

1343

00:56:06,410 --> 00:56:04,599

you can still pull out in the ratio that

1344

00:56:09,630 --> 00:56:06,420

there's actually something with enhanced

1345

00:56:11,520 --> 00:56:09,640

ratio buried in that h2 region so

1346

00:56:14,849 --> 00:56:11,530

there's three supernova remnants right

1347

00:56:16,770 --> 00:56:14,859

there for you can look at the O 3 and

1348

00:56:18,810 --> 00:56:16,780

here's the yeah these two actually

1349

00:56:21,150 --> 00:56:18,820

happen to be fairly strong in oxygen 3

1350

00:56:22,920 --> 00:56:21,160

as well compared to H alpha and so let's

1351
00:56:24,000 --> 00:56:22,930
look at the color picture the ones that

1352
00:56:25,770 --> 00:56:24,010
are bright in all three are kind of

1353
00:56:27,140 --> 00:56:25,780
whitish or even a little bluish because

1354
00:56:29,400 --> 00:56:27,150
they've got so much of that oxygen

1355
00:56:31,920 --> 00:56:29,410
emission but we already looked at the

1356
00:56:32,920 --> 00:56:31,930
ratio of the software to da choppah we

1357
00:56:36,280 --> 00:56:32,930
know those are those are

1358
00:56:39,190 --> 00:56:36,290
I this guy does not have very much o3

1359
00:56:41,200 --> 00:56:39,200
and so it comes out looking kind of

1360
00:56:43,180 --> 00:56:41,210
greenish yellow combination of the H

1361
00:56:46,569 --> 00:56:43,190
alpha and the sulphur to so that that

1362
00:56:48,309 --> 00:56:46,579
all kind of hangs together so you say

1363
00:56:51,160 --> 00:56:48,319

wow look at that guy there's a nice

1364

00:56:52,839 --> 00:56:51,170

bright possibly oxygen dominated

1365

00:56:54,790 --> 00:56:52,849

supernova remnant right well it turns

1366

00:56:56,980 --> 00:56:54,800

out that's a planetary nebula in m83

1367

00:56:59,620 --> 00:56:56,990

there's no x-ray emission associated

1368

00:57:05,410 --> 00:56:59,630

with that and so that was a close but no

1369

00:57:06,940 --> 00:57:05,420

cigar in that case so with Hubble what

1370

00:57:09,160 --> 00:57:06,950

we do is we go and we get the size of

1371

00:57:11,079 --> 00:57:09,170

these guys and we actually find some

1372

00:57:13,089 --> 00:57:11,089

additional objects as well because in

1373

00:57:15,040 --> 00:57:13,099

those confused regions at ground-based

1374

00:57:16,750 --> 00:57:15,050

resolution you you you can't find them

1375

00:57:19,839 --> 00:57:16,760

and sometimes the Hubble that they pop

1376
00:57:22,660 --> 00:57:19,849
out so here are seven fields of Hubble

1377
00:57:24,370 --> 00:57:22,670
data with c3 these two green ones were

1378
00:57:25,720 --> 00:57:24,380
actually taken shortly after the last

1379
00:57:27,700 --> 00:57:25,730
servicing mission when the camera was

1380
00:57:29,170 --> 00:57:27,710
first installed and then I came back

1381
00:57:31,630 --> 00:57:29,180
with a team and we got these other five

1382
00:57:33,520 --> 00:57:31,640
fields to kind of round out the coverage

1383
00:57:34,930 --> 00:57:33,530
and get most of the galaxies and we

1384
00:57:36,579 --> 00:57:34,940
looked at it with a bunch of continuum

1385
00:57:38,170 --> 00:57:36,589
filters the star filters and then we

1386
00:57:40,240 --> 00:57:38,180
looked at it with a bunch of these

1387
00:57:43,539 --> 00:57:40,250
emission line filters and played this

1388
00:57:44,799 --> 00:57:43,549

game over that whole galaxy and that's

1389

00:57:49,299 --> 00:57:44,809

what it looks like when you stitch it

1390

00:57:52,420 --> 00:57:49,309

all together and thanks to Zoltan Levay

1391

00:57:54,069 --> 00:57:52,430

here at the Institute for for putting

1392

00:57:56,380 --> 00:57:54,079

that pretty pretty version of it

1393

00:57:58,089 --> 00:57:56,390

together but also thanks to a couple of

1394

00:57:59,980 --> 00:57:58,099

folks here Jennifer Mack and Derek

1395

00:58:02,200 --> 00:57:59,990

hammer who are the ones that figured out

1396

00:58:04,059 --> 00:58:02,210

all the alignments and all the tweaks to

1397

00:58:06,819 --> 00:58:04,069

get it all lined up properly so that

1398

00:58:08,799 --> 00:58:06,829

Zolt could could work as magic on that

1399

00:58:11,020 --> 00:58:08,809

picture and if it looks sort of familiar

1400

00:58:12,880 --> 00:58:11,030

to you but not that familiar to you well

1401
00:58:14,770 --> 00:58:12,890
if you kind of you know cut off this

1402
00:58:16,180 --> 00:58:14,780
little wing out here and just made a

1403
00:58:17,829 --> 00:58:16,190
nice rectangle out of that and turned it

1404
00:58:19,150 --> 00:58:17,839
around sideways you get this nice

1405
00:58:22,380 --> 00:58:19,160
picture of the version that was put out

1406
00:58:25,000 --> 00:58:22,390
as a press release back in January 2014

1407
00:58:26,440 --> 00:58:25,010
that's the same data set scaled a little

1408
00:58:28,780 --> 00:58:26,450
bit differently shows the Stars a little

1409
00:58:30,910 --> 00:58:28,790
bit more dramatically and so forth but

1410
00:58:33,039 --> 00:58:30,920
that's that's a pretty famous Hubble

1411
00:58:36,339 --> 00:58:33,049
picture now and it's the same data set

1412
00:58:37,660 --> 00:58:36,349
that I'll be talking about so it's nice

1413
00:58:39,910 --> 00:58:37,670

to look at the beautiful picture of the

1414

00:58:41,079 --> 00:58:39,920

whole galaxy like this but the real

1415

00:58:42,400 --> 00:58:41,089

power of Hubble is when you start

1416

00:58:45,100 --> 00:58:42,410

zooming into it where you can see the

1417

00:58:47,470 --> 00:58:45,110

details and here are a couple

1418

00:58:48,330 --> 00:58:47,480

this is still a very large area 5,000

1419

00:58:51,250 --> 00:58:48,340

light years across

1420

00:58:53,650 --> 00:58:51,260

showing dust lanes the star formation

1421

00:58:54,940 --> 00:58:53,660

going on in here

1422

00:58:56,350 --> 00:58:54,950

this is a little closer in toward the

1423

00:58:57,970 --> 00:58:56,360

nucleus you can sit tell from the

1424

00:59:00,370 --> 00:58:57,980

background and you could just see the

1425

00:59:02,830 --> 00:59:00,380

tremendous dust lanes and stuff in this

1426
00:59:05,830 --> 00:59:02,840
galaxy but behind that these tremendous

1427
00:59:07,480 --> 00:59:05,840
regions of star formation also going on

1428
00:59:11,650 --> 00:59:07,490
the red regions of course there were

1429
00:59:14,440 --> 00:59:11,660
hydrogen gas is being ionized by the

1430
00:59:16,390 --> 00:59:14,450
Starlight you that only happens for the

1431
00:59:18,610 --> 00:59:16,400
first maybe five million years after a

1432
00:59:20,170 --> 00:59:18,620
burst of star formation maybe ten

1433
00:59:23,110 --> 00:59:20,180
million years on the outside edge and

1434
00:59:24,910 --> 00:59:23,120
you lose that H alpha emission and it

1435
00:59:27,640 --> 00:59:24,920
leaves behind the stars and it might

1436
00:59:30,370 --> 00:59:27,650
look something like this very young star

1437
00:59:31,540 --> 00:59:30,380
forming regions very compact and

1438
00:59:33,070 --> 00:59:31,550

condensed you can see that there's

1439

00:59:35,170 --> 00:59:33,080

bright light in there lots of stars

1440

00:59:36,820 --> 00:59:35,180

there's not even resolved forming but

1441

00:59:39,040 --> 00:59:36,830

they're ionizing the gas around them

1442

00:59:41,290 --> 00:59:39,050

then maybe a little longer along the way

1443

00:59:42,940 --> 00:59:41,300

that that cluster of stars has had

1444

00:59:44,470 --> 00:59:42,950

enough time the stellar winds and a few

1445

00:59:46,630 --> 00:59:44,480

supernovae we have started to blow a

1446

00:59:48,580 --> 00:59:46,640

bubble and they're starting to move that

1447

00:59:51,040 --> 00:59:48,590

stuff away from the site of star

1448

00:59:53,440 --> 00:59:51,050

formation and then maybe you know 50 70

1449

00:59:55,660 --> 00:59:53,450

million years later that material has

1450

00:59:57,850 --> 00:59:55,670

all been dispersed and you're left with

1451
00:59:59,560 --> 00:59:57,860
a cluster of still fairly young stars

1452
01:00:01,930 --> 00:59:59,570
but you see there's a lot more red dots

1453
01:00:03,160 --> 01:00:01,940
in here those are red giant stars some

1454
01:00:05,770 --> 01:00:03,170
of the more massive stars that are now

1455
01:00:08,380 --> 01:00:05,780
started to evolve away from being blue

1456
01:00:09,910 --> 01:00:08,390
and become red giant stars so you can

1457
01:00:11,680 --> 01:00:09,920
actually look at the stellar component

1458
01:00:14,430 --> 01:00:11,690
and understand a lot about what's

1459
01:00:17,050 --> 01:00:14,440
happening with star formation

1460
01:00:19,570 --> 01:00:17,060
interestingly enough we don't find

1461
01:00:22,120 --> 01:00:19,580
supernovae in places like this now it's

1462
01:00:24,040 --> 01:00:22,130
partly because supernova remnants I'm

1463
01:00:26,170 --> 01:00:24,050

sorry we don't find them in regions like

1464

01:00:27,670 --> 01:00:26,180

this because the gas has all been

1465

01:00:29,050 --> 01:00:27,680

cleared out if you blow something up in

1466

01:00:32,260 --> 01:00:29,060

there it just expands out and it doesn't

1467

01:00:34,510 --> 01:00:32,270

hit anything so it never gets bright so

1468

01:00:36,010 --> 01:00:34,520

we no doubt are missing some supernova

1469

01:00:38,590 --> 01:00:36,020

remnants that happened in that in that

1470

01:00:41,140 --> 01:00:38,600

scenario but we tend to find supernova

1471

01:00:44,350 --> 01:00:41,150

remnants in regions around regions like

1472

01:00:46,780 --> 01:00:44,360

this and so for instance here is one

1473

01:00:48,490 --> 01:00:46,790

example and I'll just real briefly tell

1474

01:00:50,380 --> 01:00:48,500

you I'm not going to talk about this in

1475

01:00:52,480 --> 01:00:50,390

any detail but there's an infrared iron

1476

01:00:54,490 --> 01:00:52,490

to line that Hubble Hubble's infrared

1477

01:00:56,279 --> 01:00:54,500

channel can observe that turns out to be

1478

01:00:59,249 --> 01:00:56,289

a very nice diagnostic for

1479

01:01:00,660 --> 01:00:59,259

Jacque heated gas in this case I'm we're

1480

01:01:03,029 --> 01:01:00,670

losing the data up there but you can see

1481

01:01:05,099 --> 01:01:03,039

that this this h2 region that's

1482

01:01:07,380 --> 01:01:05,109

associated up here just is not there at

1483

01:01:10,559 --> 01:01:07,390

all in iron - and this little dot here

1484

01:01:12,539 --> 01:01:10,569

is that's a clue white means it's strong

1485

01:01:14,880 --> 01:01:12,549

in all three of my bands right it's not

1486

01:01:16,469 --> 01:01:14,890

an oxygen dominated guy but it's it's

1487

01:01:18,929 --> 01:01:16,479

bright and all three bands whereas but

1488

01:01:21,539 --> 01:01:18,939

photo wine nice stuff is not and so

1489

01:01:23,279 --> 01:01:21,549

that's a clue and it's very tiny this I

1490

01:01:25,140 --> 01:01:23,289

don't have it marked on here but that

1491

01:01:26,789 --> 01:01:25,150

circle is three arc seconds across so

1492

01:01:28,919 --> 01:01:26,799

that's way below one arc second and

1493

01:01:30,900 --> 01:01:28,929

sighs that little dot there's no star

1494

01:01:33,329 --> 01:01:30,910

there so it's not a subtraction problem

1495

01:01:36,390 --> 01:01:33,339

or anything like that and it's a strong

1496

01:01:40,349 --> 01:01:36,400

soft x-ray source so that is a young

1497

01:01:42,839 --> 01:01:40,359

supernova remnant in m83 doesn't look

1498

01:01:44,939 --> 01:01:42,849

like much but some of them are a little

1499

01:01:48,089 --> 01:01:44,949

more extended here's a little region of

1500

01:01:50,130 --> 01:01:48,099

m83 where there's a five of them in one

1501

01:01:52,259 --> 01:01:50,140

small region and so some of these guys

1502

01:01:54,539 --> 01:01:52,269

this is the emission line band over here

1503

01:01:56,219 --> 01:01:54,549

you can see little shell shapes to these

1504

01:01:58,829 --> 01:01:56,229

guys and whatnot so they're resolved

1505

01:02:00,779 --> 01:01:58,839

this one's a little more funky up here

1506

01:02:02,849 --> 01:02:00,789

all of them are bright and iron which is

1507

01:02:05,009 --> 01:02:02,859

nice to see as a matter of fact here's

1508

01:02:07,769 --> 01:02:05,019

one that's bright an iron that we don't

1509

01:02:09,599 --> 01:02:07,779

see optically we don't see an x-ray and

1510

01:02:12,059 --> 01:02:09,609

that's because it's against this dark

1511

01:02:14,939 --> 01:02:12,069

lane it's probably behind the dust and

1512

01:02:17,130 --> 01:02:14,949

this infrared line actually gets through

1513

01:02:18,660 --> 01:02:17,140

the dust and so we're finding ones that

1514

01:02:20,910 --> 01:02:18,670

we would miss otherwise because we've

1515

01:02:22,529 --> 01:02:20,920

got that iron picture as part of the

1516

01:02:23,969 --> 01:02:22,539

part of the thing but so there's five

1517

01:02:26,429 --> 01:02:23,979

supernova round this one that was not

1518

01:02:28,109 --> 01:02:26,439

known before and here we can now come in

1519

01:02:30,059 --> 01:02:28,119

and measure the sizes of those guys and

1520

01:02:35,219 --> 01:02:30,069

actually use that to understand the

1521

01:02:37,380 --> 01:02:35,229

evolution so I like to show this one

1522

01:02:41,579 --> 01:02:37,390

because this is basically a Cygnus loop

1523

01:02:43,949 --> 01:02:41,589

a big you know 7080 light year across

1524

01:02:47,819 --> 01:02:43,959

object you can see the shell is resolved

1525

01:02:48,900 --> 01:02:47,829

there it's strong at iron - there's you

1526

01:02:50,939 --> 01:02:48,910

know some stars in the region but

1527

01:02:52,859 --> 01:02:50,949

nothing that would contaminate it that

1528

01:02:54,900 --> 01:02:52,869

badly and it's a strong soft x-ray

1529

01:02:57,029 --> 01:02:54,910

source I have a spectrum of this one

1530

01:02:58,410 --> 01:02:57,039

here's the oxygen lines and the and the

1531

01:03:00,329 --> 01:02:58,420

hydrogen line that's in the blue part of

1532

01:03:01,469 --> 01:03:00,339

the spectrum and this is the red part of

1533

01:03:03,719 --> 01:03:01,479

the spectrum you can see the strong

1534

01:03:06,089 --> 01:03:03,729

sulfur lines compared to hydrogen and

1535

01:03:09,390 --> 01:03:06,099

nitrogen just what you like to see and

1536

01:03:09,630 --> 01:03:09,400

again no evidence of broadening above

1537

01:03:14,579 --> 01:03:09,640

the

1538

01:03:19,680 --> 01:03:14,589

that's that's a Cygnus loop in a MIDI

1539

01:03:21,240 --> 01:03:19,690

315 million light-years away so we'll

1540

01:03:22,620 --> 01:03:21,250

come back to the young remnants in a

1541

01:03:24,269 --> 01:03:22,630

minute but I wanted to talk about the

1542

01:03:28,589 --> 01:03:24,279

historical supernova again for a minute

1543

01:03:30,029 --> 01:03:28,599

and in particular this object that 1957

1544

01:03:33,329 --> 01:03:30,039

D so that's a supernova that was

1545

01:03:35,730 --> 01:03:33,339

observed in 1957 so we know how old that

1546

01:03:37,109 --> 01:03:35,740

one is and then this object down here

1547

01:03:40,470 --> 01:03:37,119

that we found that I think is is

1548

01:03:41,970 --> 01:03:40,480

comparable in some ways to was

1549

01:03:43,799 --> 01:03:41,980

definitely a young supernova remnant is

1550

01:03:48,990 --> 01:03:43,809

in some ways it's similar in some ways

1551

01:03:51,150 --> 01:03:49,000

it's different from from 57 D so here's

1552

01:03:53,309 --> 01:03:51,160

a couple of pictures this is the Chandra

1553

01:03:55,950 --> 01:03:53,319

x-ray picture in this case it's a blue

1554

01:03:57,269 --> 01:03:55,960

hard x-ray source which is not typical

1555

01:03:59,460 --> 01:03:57,279

for a supernova in this so usually these

1556

01:04:01,170 --> 01:03:59,470

red colors I might mean it's kind of

1557

01:04:03,690 --> 01:04:01,180

pulsar in it because pulsars have a

1558

01:04:05,519 --> 01:04:03,700

different kind of x-ray spectrum okay at

1559

01:04:07,859 --> 01:04:05,529

ground-based resolution this is what it

1560

01:04:10,410 --> 01:04:07,869

looked like there was a blue dot oxygen

1561

01:04:11,579 --> 01:04:10,420

blue dot and it had some red stuff next

1562

01:04:13,559 --> 01:04:11,589

to it but we really couldn't see what

1563

01:04:15,059 --> 01:04:13,569

was going on and so these two now are

1564

01:04:17,370 --> 01:04:15,069

the Hubble pictures that have been

1565

01:04:19,019 --> 01:04:17,380

zoomed in to that little yellow circle

1566

01:04:20,940 --> 01:04:19,029

up there so we're just looking at that

1567

01:04:25,079 --> 01:04:20,950

region and sure enough what do we see

1568

01:04:26,970 --> 01:04:25,089

blue dominated by oxygen 3 that's the 57

1569

01:04:29,220 --> 01:04:26,980

D and here's some H alpha emission

1570

01:04:31,160 --> 01:04:29,230

that's associated nearby but it is not

1571

01:04:34,559 --> 01:04:31,170

not part of that structure that we see

1572

01:04:36,329 --> 01:04:34,569

there and so that should show broad

1573

01:04:37,680 --> 01:04:36,339

oxygen lines if we're know what we're

1574

01:04:40,829 --> 01:04:37,690

doing and sure enough in the spectra

1575

01:04:42,870 --> 01:04:40,839

here we have the oxygen line and it's

1576

01:04:46,140 --> 01:04:42,880

very very broad interestingly enough

1577

01:04:48,089 --> 01:04:46,150

from 1989 to 2011 when we got the last

1578

01:04:50,220 --> 01:04:48,099

spectrum it's actually faded quite a bit

1579

01:04:52,620 --> 01:04:50,230

but it's still there still broad lines

1580

01:04:53,279 --> 01:04:52,630

it's associated with a little cluster of

1581

01:04:56,700 --> 01:04:53,289

stars

1582

01:04:58,789 --> 01:04:56,710

and we can actually go in and do

1583

01:05:00,990 --> 01:04:58,799

photometry for those stars and

1584

01:05:02,910 --> 01:05:01,000

understand what the most massive stars

1585

01:05:05,099 --> 01:05:02,920

that are in that cluster are and the

1586

01:05:07,529 --> 01:05:05,109

most massive stars are about 17 times

1587

01:05:09,930 --> 01:05:07,539

the mass of the Sun so if this one blew

1588

01:05:11,640 --> 01:05:09,940

up we had to be more massive than that

1589

01:05:13,140 --> 01:05:11,650

because the more massive they are the

1590

01:05:15,749 --> 01:05:13,150

faster they go through their life cycle

1591

01:05:17,309 --> 01:05:15,759

would blow up so it tells us it confirms

1592

01:05:21,930 --> 01:05:17,319

basically there this had to be a massive

1593

01:05:23,370 --> 01:05:21,940

star that that blew up so that's the 57

1594

01:05:26,410 --> 01:05:23,380

D guy

1595

01:05:28,599 --> 01:05:26,420

this other one just take a minute to

1596

01:05:30,910 --> 01:05:28,609

explain these are ground-based pictures

1597

01:05:33,069 --> 01:05:30,920

this is the Hubble pictures zoomed in

1598

01:05:34,809 --> 01:05:33,079

again so the scale changes between those

1599

01:05:36,969 --> 01:05:34,819

two and here's the spectrum of that

1600

01:05:38,829 --> 01:05:36,979

object that we found after after the

1601

01:05:42,459 --> 01:05:38,839

fact the story goes like this

1602

01:05:44,259 --> 01:05:42,469

we we found this object in our

1603

01:05:45,969 --> 01:05:44,269

ground-based data we actually thought

1604

01:05:48,069 --> 01:05:45,979

that there was a larger object and that

1605

01:05:51,789 --> 01:05:48,079

this was a bright not maybe on one side

1606

01:05:53,589 --> 01:05:51,799

of the shell there but when we looked at

1607

01:05:55,120 --> 01:05:53,599

the x-ray data the x-ray data really

1608

01:05:57,219 --> 01:05:55,130

seemed to line up with that bright dot

1609

01:05:58,930 --> 01:05:57,229

up there and so we came in with a

1610

01:06:01,180 --> 01:05:58,940

spectrograph and took a spectrum of that

1611

01:06:04,209 --> 01:06:01,190

dot and this is what it looked like and

1612

01:06:05,739 --> 01:06:04,219

it's very broad lines very high

1613

01:06:08,349 --> 01:06:05,749

expansion velocity so it's a young

1614

01:06:10,719 --> 01:06:08,359

object and the reason we found this with

1615

01:06:12,489 --> 01:06:10,729

our three little filters right I put an

1616

01:06:13,749 --> 01:06:12,499

H off of narrow filter there and a

1617

01:06:15,640 --> 01:06:13,759

software to filter there and it looked

1618

01:06:18,009 --> 01:06:15,650

like it was strong and software to 2h

1619

01:06:19,690 --> 01:06:18,019

alpha and yet it's got this huge feature

1620

01:06:22,269 --> 01:06:19,700

that goes over that entire region of the

1621

01:06:24,489 --> 01:06:22,279

spectrum so I just got lucky on Yellin

1622

01:06:26,079 --> 01:06:24,499

and it does have the oxygen as well so

1623

01:06:28,690 --> 01:06:26,089

we found that it is an interesting

1624

01:06:31,120 --> 01:06:28,700

object but we didn't know that it was

1625

01:06:33,549 --> 01:06:31,130

had this high velocity until we got the

1626

01:06:36,099 --> 01:06:33,559

spectrum of it well now we bring Hubble

1627

01:06:38,259 --> 01:06:36,109

into the picture because Hubble can see

1628

01:06:39,969 --> 01:06:38,269

the bright night and it actually can't

1629

01:06:42,130 --> 01:06:39,979

detect the low surface brightness stuff

1630

01:06:45,609 --> 01:06:42,140

adjacent to it there but here's H alpha

1631

01:06:48,579 --> 01:06:45,619

sulphur 203 just like you know filters

1632

01:06:50,170 --> 01:06:48,589

got H-alpha and but it's very very tiny

1633

01:06:52,539 --> 01:06:50,180

it's just a dot it looks like a star

1634

01:06:54,670 --> 01:06:52,549

it's not as unresolved it's very tiny

1635

01:06:58,239 --> 01:06:54,680

so from the upper limit on the size of

1636

01:07:00,009 --> 01:06:58,249

the object and the expansion velocity

1637

01:07:01,329 --> 01:07:00,019

that we got from the spectrum we can say

1638

01:07:03,309 --> 01:07:01,339

that it has to be less than a hundred

1639

01:07:06,370 --> 01:07:03,319

years old so this is the one that we

1640

01:07:09,839 --> 01:07:06,380

think is a young supernova remnant that

1641

01:07:12,519 --> 01:07:09,849

where the supernova was not observed

1642

01:07:14,950 --> 01:07:12,529

well okay so we're trying to find these

1643

01:07:16,599 --> 01:07:14,960

young guys and what did we find

1644

01:07:19,420 --> 01:07:16,609

well if we just look at the sizes of

1645

01:07:21,969 --> 01:07:19,430

them the ones that are less than that 35

1646

01:07:25,630 --> 01:07:21,979

light years 11 parsecs forgot to change

1647

01:07:26,950 --> 01:07:25,640

that sorry sighs we found about the

1648

01:07:28,299 --> 01:07:26,960

right number of objects we've got 60

1649

01:07:30,599 --> 01:07:28,309

objects that are about the right size

1650

01:07:34,200 --> 01:07:30,609

that are tiny little supernova remnants

1651
01:07:36,700 --> 01:07:34,210
number of them are x-ray sources as well

1652
01:07:36,940 --> 01:07:36,710
but the only those two objects that I

1653
01:07:42,190 --> 01:07:36,950
show

1654
01:07:44,349 --> 01:07:42,200
minute that looked anything like we

1655
01:07:47,050 --> 01:07:44,359
expected for those ejected dominated

1656
01:07:50,079 --> 01:07:47,060
objects what do the rest of them look

1657
01:07:51,099 --> 01:07:50,089
like well they look like this like kind

1658
01:07:54,160 --> 01:07:51,109
of like that when I showed you a minute

1659
01:07:56,620 --> 01:07:54,170
ago here's another one a tiny little dot

1660
01:07:59,620 --> 01:07:56,630
white right in all three bands not

1661
01:08:02,050 --> 01:07:59,630
dominated by blue by the oxygen strong

1662
01:08:04,290 --> 01:08:02,060
iron source strong soft x-ray source

1663
01:08:07,210 --> 01:08:04,300

there's a few stars in the neighborhood

1664

01:08:10,480 --> 01:08:07,220

fairly blue stars so one of them blew up

1665

01:08:13,810 --> 01:08:10,490

and we take the spectrum no high

1666

01:08:17,170 --> 01:08:13,820

velocities this object is the size of

1667

01:08:20,260 --> 01:08:17,180

Cassiopeia A and yet it has no high

1668

01:08:24,309 --> 01:08:20,270

velocity material and its spectrum looks

1669

01:08:26,979 --> 01:08:24,319

like the Cygnus loop or the other ejecta

1670

01:08:28,510 --> 01:08:26,989

or not the other is M dominated

1671

01:08:31,380 --> 01:08:28,520

inspector the normal supernova resonance

1672

01:08:35,200 --> 01:08:31,390

it does not show evidence of being

1673

01:08:37,690 --> 01:08:35,210

ejected dominated so where are all the

1674

01:08:39,340 --> 01:08:37,700

KSA's this is the third object that has

1675

01:08:40,979 --> 01:08:39,350

some hope of being a castaway we don't

1676

01:08:45,640 --> 01:08:40,989

have a spectrum of this one yet but

1677

01:08:47,769 --> 01:08:45,650

again in oxygen and here's the there's

1678

01:08:49,539 --> 01:08:47,779

no star right there it's right on the

1679

01:08:50,800 --> 01:08:49,549

edge of the bright nucleus of the galaxy

1680

01:08:52,510 --> 01:08:50,810

that right over here is the bright

1681

01:08:55,870 --> 01:08:52,520

bright nucleus of the galaxy so this is

1682

01:08:58,630 --> 01:08:55,880

right on the edge this guy magenta color

1683

01:09:00,459 --> 01:08:58,640

means it's bright an H alpha and o3 it's

1684

01:09:03,099 --> 01:09:00,469

not what we expect exactly but it does

1685

01:09:05,140 --> 01:09:03,109

have the strong L 3 it is very compact

1686

01:09:06,340 --> 01:09:05,150

and there's no star there so I I think

1687

01:09:07,660 --> 01:09:06,350

if we get a spectrum with this that we

1688

01:09:09,490 --> 01:09:07,670

have some hope of maybe seeing high

1689

01:09:12,490 --> 01:09:09,500

velocities and that one so that's the

1690

01:09:14,740 --> 01:09:12,500

third one that's kind of like Cassie but

1691

01:09:16,749 --> 01:09:14,750

we're not finding 60 or hundred of these

1692

01:09:18,340 --> 01:09:16,759

things like we expected even and we

1693

01:09:22,660 --> 01:09:18,350

found the young ones and they don't look

1694

01:09:25,360 --> 01:09:22,670

like this so here's what's going on

1695

01:09:27,220 --> 01:09:25,370

apparently we're seeing we're not seeing

1696

01:09:29,079 --> 01:09:27,230

counterparts to these local ones that

1697

01:09:31,320 --> 01:09:29,089

we've seen where they get this big and

1698

01:09:34,329 --> 01:09:31,330

still show evidence of high velocity and

1699

01:09:38,200 --> 01:09:34,339

ejecta dominated we're seeing things the

1700

01:09:39,880 --> 01:09:38,210

size of Cassie or the crab that already

1701

01:09:42,220 --> 01:09:39,890

looked like the Cygnus loop that have

1702

01:09:43,870 --> 01:09:42,230

evolved beyond the ejecta dominated

1703

01:09:45,729 --> 01:09:43,880

phase into this phase where you're

1704

01:09:49,720 --> 01:09:45,739

looking at shocked interstellar gas

1705

01:09:50,650 --> 01:09:49,730

surrounding the object so the supernova

1706

01:09:53,790 --> 01:09:50,660

remnants and m83

1707

01:09:56,290 --> 01:09:53,800

you're evolving very quickly beyond the

1708

01:10:00,970 --> 01:09:56,300

ejecta phase and into the what's called

1709

01:10:03,670 --> 01:10:00,980

the radiative phase of evolution so we

1710

01:10:05,830 --> 01:10:03,680

didn't find what we expected to find and

1711

01:10:07,510 --> 01:10:05,840

these cards will be on sale in the lobby

1712

01:10:10,930 --> 01:10:07,520

if you wanted I want to send it to me

1713

01:10:12,370 --> 01:10:10,940

after the meeting you know because you

1714

01:10:13,690 --> 01:10:12,380

know sometimes it doesn't work out the

1715

01:10:17,740 --> 01:10:13,700

way you expect it to work out you know

1716

01:10:21,340 --> 01:10:17,750

but so I guess this is probably the most

1717

01:10:26,110 --> 01:10:21,350

most appropriate one for my situation if

1718

01:10:27,970 --> 01:10:26,120

you but when science gives you lemons

1719

01:10:30,040 --> 01:10:27,980

well you make lemonade right and so

1720

01:10:31,510 --> 01:10:30,050

we've learned a lot we've learned some

1721

01:10:33,610 --> 01:10:31,520

really interesting things about this

1722

01:10:35,970 --> 01:10:33,620

galaxy and a couple of things that I

1723

01:10:38,680 --> 01:10:35,980

really didn't highlight to you too much

1724

01:10:42,070 --> 01:10:38,690

I'll do number two here first basically

1725

01:10:44,020 --> 01:10:42,080

m83 has very high chemical element

1726

01:10:46,840 --> 01:10:44,030

abundances even compared to the Milky

1727

01:10:48,610 --> 01:10:46,850

Way we had the small Magellanic Cloud

1728

01:10:52,390 --> 01:10:48,620

the Large Magellanic Cloud the Milky Way

1729

01:10:54,910 --> 01:10:52,400

and m83 the abundances go from about 0.2

1730

01:10:57,960 --> 01:10:54,920

times the sun's abundance to about 0.5

1731

01:11:01,630 --> 01:10:57,970

and the LMC to the Milky Way abundances

1732

01:11:04,000 --> 01:11:01,640

this galaxy has twice solar abundances

1733

01:11:06,640 --> 01:11:04,010

over that entire galaxy and probably

1734

01:11:08,380 --> 01:11:06,650

even higher in the center and I think

1735

01:11:10,870 --> 01:11:08,390

those high abundances are part of the

1736

01:11:12,970 --> 01:11:10,880

story the other part of it is the this

1737

01:11:15,460 --> 01:11:12,980

x-ray data remember shows all this

1738

01:11:18,190 --> 01:11:15,470

diffuse hot gas in the spiral arms

1739

01:11:21,310 --> 01:11:18,200

that's high density high pressure gas in

1740

01:11:23,740 --> 01:11:21,320

the interstellar medium of m83 so let's

1741

01:11:26,110 --> 01:11:23,750

put these two things together hi

1742

01:11:27,730 --> 01:11:26,120

chemical element abundances in a massive

1743

01:11:30,310 --> 01:11:27,740

star allow us to start to have a very

1744

01:11:32,590 --> 01:11:30,320

strong wind that would blow material off

1745

01:11:35,290 --> 01:11:32,600

before the star explodes but if we've

1746

01:11:37,630 --> 01:11:35,300

got a hot high-pressure is M around it

1747

01:11:39,460 --> 01:11:37,640

that stuff can't go very far it hangs

1748

01:11:41,650 --> 01:11:39,470

out right around the outside of where

1749

01:11:43,990 --> 01:11:41,660

the star is going to explode so when the

1750

01:11:45,460 --> 01:11:44,000

star explodes it rams into that stuff

1751

01:11:47,590 --> 01:11:45,470

very quickly and you get a bright

1752

01:11:50,710 --> 01:11:47,600

radiative supernova remnant very quickly

1753

01:11:52,690 --> 01:11:50,720

at a small diameter and so I think

1754

01:11:54,130 --> 01:11:52,700

that's what's tricked us here we're

1755

01:11:57,640 --> 01:11:54,140

finding the young remnants but they're

1756

01:11:59,140 --> 01:11:57,650

not catching them in that ejecta

1757

01:12:01,750 --> 01:11:59,150

dominated phase that we were hoping to

1758

01:12:04,060 --> 01:12:01,760

find and it turns out this is very

1759

01:12:05,680 --> 01:12:04,070

interesting and we're still trying to

1760

01:12:07,899 --> 01:12:05,690

pieced together models and things that

1761

01:12:10,030 --> 01:12:07,909

would that would help us understand

1762

01:12:11,979 --> 01:12:10,040

exactly how that all transpires but

1763

01:12:16,750 --> 01:12:11,989

that's our working model for what's

1764

01:12:19,569 --> 01:12:16,760

going on so worried basically we did

1765

01:12:22,060 --> 01:12:19,579

find a lot of young supernova remnants

1766

01:12:24,790 --> 01:12:22,070

as we expected but we did not find them

1767

01:12:26,890 --> 01:12:24,800

to be in this ejected dominated state

1768

01:12:29,740 --> 01:12:26,900

that we did expect and and I just talked

1769

01:12:31,000 --> 01:12:29,750

about the reasons I hope as we get

1770

01:12:33,040 --> 01:12:31,010

additional spectra for some of these

1771

01:12:35,770 --> 01:12:33,050

candidate objects that we might find a

1772

01:12:37,600 --> 01:12:35,780

couple more of those young objects with

1773

01:12:40,510 --> 01:12:37,610

the very broad lines like that one that

1774

01:12:41,649 --> 01:12:40,520

I showed you but that's not no guarantee

1775

01:12:43,930 --> 01:12:41,659

and it's certainly not going to get us

1776

01:12:47,260 --> 01:12:43,940

up to a hundred of those young objects

1777

01:12:48,850 --> 01:12:47,270

that way so that's it and thanks for

1778

01:12:50,050 --> 01:12:48,860

listening and this is just kind of

1779

01:12:51,910 --> 01:12:50,060

showing you where all the supernova

1780

01:12:54,370 --> 01:12:51,920

remnants are across the galaxy and the

1781

01:12:55,959 --> 01:12:54,380

optical and the x-ray pictures I'd be

1782

01:13:26,500 --> 01:12:55,969

glad to try to answer some questions for

1783

01:13:31,880 --> 01:13:29,660

only sort of indirectly like versus that

1784

01:13:33,200 --> 01:13:31,890

one that I said from the it was seen an

1785

01:13:34,850 --> 01:13:33,210

iron and it wasn't seen in the other

1786

01:13:35,900 --> 01:13:34,860

wavelengths and that iron gets through

1787

01:13:37,670 --> 01:13:35,910

the dust and they're sitting right on

1788

01:13:39,650 --> 01:13:37,680

the dust Lane I know it must be behind

1789

01:13:41,260 --> 01:13:39,660

the dust but other than that I don't

1790

01:13:44,570 --> 01:13:41,270

really have depth into the galaxy

1791

01:13:45,860 --> 01:13:44,580

information that's very small distance

1792

01:13:48,080 --> 01:13:45,870

compared to the distance from us to the

1793

01:13:49,100 --> 01:13:48,090

galaxy so it's just they're essentially

1794

01:13:52,330 --> 01:13:49,110

all at the same distance from my

1795

01:13:56,240 --> 01:13:52,340

perspective but yeah it would be hard to

1796

01:14:06,210 --> 01:13:56,250

pin that down with any certainty yes

1797

01:14:21,939 --> 01:14:08,430

in the actual supernova spectrum are in

1798

01:14:33,379 --> 01:14:25,899

so from the supernova itself basically

1799

01:14:35,719 --> 01:14:33,389

from the ejecta so the spectrum would

1800

01:14:38,509 --> 01:14:35,729

tell me and if the spectrum is emission

1801
01:14:40,520 --> 01:14:38,519
lines I can even get the composition of

1802
01:14:42,350 --> 01:14:40,530
the of the material and so for instance

1803
01:14:44,600 --> 01:14:42,360
an can say that yellow stuff in the

1804
01:14:47,899 --> 01:14:44,610
Hubble picture there was dominated by

1805
01:14:51,589 --> 01:14:47,909
oxygen and sulfur and argon and calcium

1806
01:14:53,000 --> 01:14:51,599
emission no hydrogen no nitrogen that's

1807
01:14:54,350 --> 01:14:53,010
that's a clue right there that it's a

1808
01:14:56,479 --> 01:14:54,360
massive star because that's the kind of

1809
01:14:59,810 --> 01:14:56,489
stuff you get from what's called oxygen

1810
01:15:00,949 --> 01:14:59,820
burning and so forth so you but I could

1811
01:15:01,910 --> 01:15:00,959
look in a different spot and I'd see a

1812
01:15:03,560 --> 01:15:01,920
different spectrum and it would have a

1813
01:15:05,449 --> 01:15:03,570

different composition it came from a

1814

01:15:07,759 --> 01:15:05,459

different layer in the star or whatever

1815

01:15:09,620 --> 01:15:07,769

of course as we go to m83 or longer

1816

01:15:11,719 --> 01:15:09,630

larger distances we can't see the

1817

01:15:14,379 --> 01:15:11,729

individual knots like we see in kasi and

1818

01:15:16,819 --> 01:15:14,389

so you get more of an ensemble spectrum

1819

01:15:18,469 --> 01:15:16,829

instead I if I didn't answer your

1820

01:15:19,129 --> 01:15:18,479

question come up and hold try it don't

1821

01:15:32,810 --> 01:15:19,139

try again

1822

01:15:35,899 --> 01:15:32,820

yes sir it could in principle although

1823

01:15:37,399 --> 01:15:35,909

the vast majority of the core collapse

1824

01:15:39,410 --> 01:15:37,409

remnants now the Crab Nebula is

1825

01:15:41,929 --> 01:15:39,420

different I'll give you that but most of

1826

01:15:44,359 --> 01:15:41,939

them explode there they're flying out

1827

01:15:46,669 --> 01:15:44,369

very rapidly and then eventually they're

1828

01:15:47,540 --> 01:15:46,679

going to slow down with expansion they

1829

01:15:50,299 --> 01:15:47,550

still down with time they don't

1830

01:15:52,009 --> 01:15:50,309

accelerate the Crab Nebula is different

1831

01:15:54,500 --> 01:15:52,019

because it's got that active pulsar in

1832

01:15:56,810 --> 01:15:54,510

there and that pulsar that's spinning

1833

01:16:00,520 --> 01:15:56,820

pulsar you got a one point four solar

1834

01:16:03,169 --> 01:16:00,530

mass object spinning 30 times a second

1835

01:16:04,640 --> 01:16:03,179

mind-boggling so that energy coming off

1836

01:16:06,080 --> 01:16:04,650

of that had particles and magnetic

1837

01:16:08,779 --> 01:16:06,090

fields and whatnot is what energizes

1838

01:16:11,929 --> 01:16:08,789

that blue diffuse gas in the middle of

1839

01:16:13,160 --> 01:16:11,939

the Crab Nebula and that synchrotron is

1840

01:16:15,529 --> 01:16:13,170

called synchrotron emission that

1841

01:16:17,600 --> 01:16:15,539

emission is actually pushing out on the

1842

01:16:19,270 --> 01:16:17,610

filaments and accelerating them so

1843

01:16:21,290 --> 01:16:19,280

they're actually going faster with time

1844

01:16:23,120 --> 01:16:21,300

even though it's only going 1,800

1845

01:16:25,279 --> 01:16:23,130

kilometers per second compared to 10,000

1846

01:16:27,169 --> 01:16:25,289

that was a must have been a low-energy

1847

01:16:29,029 --> 01:16:27,179

explosion or something that just didn't

1848

01:16:31,640 --> 01:16:29,039

start it off that fast but it's actually

1849

01:16:33,739 --> 01:16:31,650

being accelerated yeah now but most of

1850

01:16:34,760 --> 01:16:33,749

them it's just boom it goes off they fly

1851

01:16:38,780 --> 01:16:34,770

out and eventually

1852

01:16:40,820 --> 01:16:38,790

slow down yeah yeah so for cafe for

1853

01:16:43,160 --> 01:16:40,830

instance interesting enough can't say

1854

01:16:45,530 --> 01:16:43,170

this young is 340 plus or minus a few

1855

01:16:49,070 --> 01:16:45,540

year object in our own galaxy the

1856

01:16:52,250 --> 01:16:49,080

supernova was not seen in 16 roughly

1857

01:16:54,710 --> 01:16:52,260

1680 and here we've got the Chinese have

1858

01:16:58,520 --> 01:16:54,720

observations to go back to yellow BC

1859

01:17:00,290 --> 01:16:58,530

times right and and as somehow in 1680

1860

01:17:01,640 --> 01:17:00,300

even with European observers and it was

1861

01:17:02,150 --> 01:17:01,650

placed well in the northern sky and

1862

01:17:04,820 --> 01:17:02,160

everything like that

1863

01:17:07,940 --> 01:17:04,830

they didn't see the supernova now maybe

1864

01:17:10,040 --> 01:17:07,950

it was a sub luminous supernova but even

1865

01:17:12,290 --> 01:17:10,050

so it's in our galaxy it shouldn't it

1866

01:17:14,450 --> 01:17:12,300

should have been easily visible probably

1867

01:17:16,400 --> 01:17:14,460

but to get the age of it they look at

1868

01:17:19,990 --> 01:17:16,410

the fastest material they see flying out

1869

01:17:22,940 --> 01:17:20,000

right now assume that's unda celebrated

1870

01:17:24,110 --> 01:17:22,950

and look at its proper motion and then

1871

01:17:25,960 --> 01:17:24,120

they take that backwards in time and

1872

01:17:35,420 --> 01:17:25,970

that's how they came up with the 1680

1873

01:17:37,520 --> 01:17:35,430

number for that one you know that is

1874

01:17:41,060 --> 01:17:37,530

difficult to determine supernova

1875

01:17:43,460 --> 01:17:41,070

remnants from type 1a supernovae versus

1876

01:17:45,140 --> 01:17:43,470

core-collapse how does that uncertainty

1877

01:17:48,200 --> 01:17:45,150

play into the star formation

1878

01:17:49,910 --> 01:17:48,210

calculations or other information so the

1879

01:17:51,500 --> 01:17:49,920

idea is you were looking at it this you

1880

01:17:52,970 --> 01:17:51,510

showed a lot in the spectra that you're

1881

01:17:55,040 --> 01:17:52,980

you know almost I almost sort of a

1882

01:17:57,800 --> 01:17:55,050

case-by-case basis you have to figure

1883

01:17:59,870 --> 01:17:57,810

out what the progenitor was right how

1884

01:18:01,490 --> 01:17:59,880

does that play into the star formation

1885

01:18:04,490 --> 01:18:01,500

rate that calculations what I do with

1886

01:18:07,010 --> 01:18:04,500

this yeah so it's an area of ongoing

1887

01:18:08,570 --> 01:18:07,020

research basically once the objects have

1888

01:18:10,580 --> 01:18:08,580

expanded to the point that they're just

1889

01:18:12,650 --> 01:18:10,590

shocking the interstellar gas around

1890

01:18:13,850 --> 01:18:12,660

them and expanding you can't tell what

1891

01:18:16,280 --> 01:18:13,860

kind of a star it was that blew up

1892

01:18:19,970 --> 01:18:16,290

without knowledge of the supernova

1893

01:18:23,030 --> 01:18:19,980

itself but you can play some games you

1894

01:18:24,800 --> 01:18:23,040

can say wow here's the supernova remnant

1895

01:18:27,590 --> 01:18:24,810

it's right next to this big cluster of

1896

01:18:29,540 --> 01:18:27,600

blue blue massive stars probably a core

1897

01:18:31,310 --> 01:18:29,550

collapse even if you didn't see the

1898

01:18:33,260 --> 01:18:31,320

supernova right and then taking it the

1899

01:18:34,670 --> 01:18:33,270

other way when you see a supernova room

1900

01:18:38,750 --> 01:18:34,680

that it's kind of out in the middle of

1901

01:18:40,310 --> 01:18:38,760

nowhere and there's no young star

1902

01:18:42,850 --> 01:18:40,320

cluster around or anything like that you

1903

01:18:45,410 --> 01:18:42,860

could say that was probably a type 1a

1904

01:18:46,850 --> 01:18:45,420

exploding white dwarf type 1a

1905

01:18:49,490 --> 01:18:46,860

supernovae there's different types of

1906

01:18:51,290 --> 01:18:49,500

supernovae and so you could look at an

1907

01:18:54,140 --> 01:18:51,300

ensemble in a galaxy like this Medina

1908

01:18:55,520 --> 01:18:54,150

1031 in particular and they try to make

1909

01:18:57,290 --> 01:18:55,530

those correlations and try to look at

1910

01:18:58,729 --> 01:18:57,300

those subsets separate from each other

1911

01:19:01,339 --> 01:18:58,739

and see if they can find correlations

1912

01:19:02,689 --> 01:19:01,349

and stuff like that but it's it's an

1913

01:19:06,500 --> 01:19:02,699

uncertain business if you haven't seen

1914

01:19:12,859 --> 01:19:06,510

the supernova yeah you know other

1915

01:19:19,189 --> 01:19:12,869

questions i warm down I check online to

1916

01:19:21,890 --> 01:19:20,570

yeah you've already answered the

1917

01:19:52,650 --> 01:19:21,900

question about how you determine the age

1918

01:19:58,300 --> 01:19:55,600

well they're mostly in the comments are

1919

01:20:00,700 --> 01:19:58,310

mostly ice they have an admixture it's

1920

01:20:02,620 --> 01:20:00,710

just basically whatever came together to

1921

01:20:03,850 --> 01:20:02,630

make the object right so what depending

1922

01:20:05,890 --> 01:20:03,860

on what part of the solar system they

1923

01:20:07,210 --> 01:20:05,900

formed and what the materials were

1924

01:20:11,680 --> 01:20:07,220

around when they form they have

1925

01:20:13,660 --> 01:20:11,690

different admixture of ices versus rocky

1926

01:20:16,450 --> 01:20:13,670

dusty stuff you know there's a lot we

1927

01:20:17,890 --> 01:20:16,460

look at your stars that are forming

1928

01:20:20,470 --> 01:20:17,900

planets right now and they have discs of

1929

01:20:22,480 --> 01:20:20,480

dust and gas around them that's the

1930

01:20:24,070 --> 01:20:22,490

stuff that some of which ends up making

1931

01:20:26,380 --> 01:20:24,080

comments right and so it's it's a

1932

01:20:27,820 --> 01:20:26,390

mixture of gas and dust and you just get

1933

01:20:30,880 --> 01:20:27,830

different comets will have a slightly

1934

01:20:32,290 --> 01:20:30,890

different mixture of those temperature

1935

01:20:34,000 --> 01:20:32,300

would be a big factor yeah right well

1936

01:20:35,860 --> 01:20:34,010

also you recognize that if you examine

1937

01:20:39,400 --> 01:20:35,870

the surface of a comet you're not going

1938

01:20:42,220 --> 01:20:39,410

to find a lot of fresh ice because as it

1939

01:20:44,830 --> 01:20:42,230

goes goes past those volatiles will go

1940

01:20:47,050 --> 01:20:44,840

away on the surface of the comet so at

1941

01:20:49,360 --> 01:20:47,060

the part of the idea the Deep Impact

1942

01:20:52,120 --> 01:20:49,370

mission was to try and look at the

1943

01:20:55,080 --> 01:20:52,130

subsurface material that spews out when

1944

01:20:59,280 --> 01:20:55,090

we basically through a washing machine

1945

01:21:08,410 --> 01:20:59,290

into a comet at 25,000 miles an hour by

1946

01:21:09,430 --> 01:21:08,420

my analogy yeah okay is there somebody

1947

01:21:11,320 --> 01:21:09,440

from the Maryland Space Grant

1948

01:21:14,170 --> 01:21:11,330

Observatory here to take people across

1949

01:21:17,830 --> 01:21:14,180

the street I do not see that person I

1950

01:21:19,990 --> 01:21:17,840

will talk to them next month and make

1951

01:21:23,620 --> 01:21:20,000

sure that they either show up or let me

1952

01:21:26,260 --> 01:21:23,630

know with an email let's see next month

1953

01:21:31,090 --> 01:21:26,270

we have Toby marriage talking about the

1954

01:21:34,300 --> 01:21:31,100

cosmology large angular scale survey and

1955

01:21:35,800 --> 01:21:34,310

that will be on November 1st all right

1956

01:21:39,040 --> 01:21:35,810

that is a week before Election Day so

1957

01:21:40,710 --> 01:21:39,050

you know you can won't have to deal with

1958

01:21:43,180 --> 01:21:40,720

any of the election stuff that night

1959

01:21:44,740 --> 01:21:43,190

hopefully we maybe will have to deal

1960

01:21:46,960 --> 01:21:44,750

with the a the oriole so I wouldn't

1961

01:21:48,340 --> 01:21:46,970

wouldn't mind it that that happened but

1962

01:21:57,380 --> 01:21:48,350

ladies and gentlemen let's give Bill one

1963

01:22:05,070 --> 01:22:03,000

did anybody leave a thermal cup the

1964

01:22:08,280 --> 01:22:05,080

facilities found this two months ago I

1965

01:22:12,780 --> 01:22:08,290

think in August they handed it to me