

1
00:00:00,000 --> 00:00:04,528
well then I am dr. Frank summers of the

2
00:00:02,279 --> 00:00:07,528
Space Telescope Science Institute and it

3
00:00:04,528 --> 00:00:10,559
is my pleasure to welcome you here on

4
00:00:07,528 --> 00:00:13,379
this special night as you can see we are

5
00:00:10,558 --> 00:00:15,088
one week late it is January 13th and not

6
00:00:13,380 --> 00:00:17,399
the second Tuesday not the first Tuesday

7
00:00:15,089 --> 00:00:19,829
but you could also see you've got the

8
00:00:17,399 --> 00:00:21,989
really cool new seats and the wonderful

9
00:00:19,829 --> 00:00:24,000
new carpeting the they finished the

10
00:00:21,989 --> 00:00:25,709
auditorium retrofit which is why they

11
00:00:24,000 --> 00:00:27,990
didn't let me have the Pope f-series

12
00:00:25,710 --> 00:00:30,000
last week which was good because I was

13
00:00:27,989 --> 00:00:31,439
in Seattle Washington last week for the

14
00:00:30,000 --> 00:00:33,808
American Astronomical Society conference

15
00:00:31,439 --> 00:00:36,030
so I wouldn't have been here had we had

16
00:00:33,808 --> 00:00:37,859
beheld it last week so it's great that

17
00:00:36,030 --> 00:00:41,960
both you and I can be here tonight

18
00:00:37,859 --> 00:00:41,960
especially since on the speaker tonight

19
00:00:43,609 --> 00:00:47,759
who haven't been here before

20
00:00:45,600 --> 00:00:50,460
we have lithographs over all the table

21
00:00:47,759 --> 00:00:52,738
over there if you did not get one on

22
00:00:50,460 --> 00:00:54,750
your way in grab one on your way out the

23
00:00:52,738 --> 00:01:00,149
lithographs are of the galaxy cluster

24
00:00:54,750 --> 00:01:02,369
Abell 2744 a very large cluster of

25
00:01:00,149 --> 00:01:05,189
galaxies so large it produces

26
00:01:02,369 --> 00:01:07,590
gravitational lensing and is being used

27
00:01:05,188 --> 00:01:09,478
as part of the frontier field survey a

28
00:01:07,590 --> 00:01:12,570
little bit of which I will talk about in

29

00:01:09,478 --> 00:01:15,840
my talk tonight speaking of which I am

30
00:01:12,569 --> 00:01:17,879
the speaker tonight giving my 25 years

31
00:01:15,840 --> 00:01:20,430
of Hubble I had actually expected to do

32
00:01:17,879 --> 00:01:21,868
this talk in April because the 25th

33
00:01:20,430 --> 00:01:24,570
anniversary is in April

34
00:01:21,868 --> 00:01:27,299
but we decided to get the festivities

35
00:01:24,569 --> 00:01:29,578
going early right we actually released

36
00:01:27,299 --> 00:01:32,250
the 20 of the the major 25th anniversary

37
00:01:29,578 --> 00:01:34,589
image last Monday at the double-a s

38
00:01:32,250 --> 00:01:36,450
meeting in Seattle and so I said alright

39
00:01:34,590 --> 00:01:37,680
great if we're gonna do that I might as

40
00:01:36,450 --> 00:01:40,770
well go ahead and kick off the year with

41
00:01:37,680 --> 00:01:43,170
the 25 years of Hubble talk anyway it's

42
00:01:40,769 --> 00:01:45,599
also kind of difficult to get a January

43
00:01:43,170 --> 00:01:47,909

speaker nobody wants to commit to doing

44

00:01:45,599 --> 00:01:49,500

the talk after the holidays this has

45

00:01:47,909 --> 00:01:51,630

happened to me every year I've been

46

00:01:49,500 --> 00:01:55,200

running the palm of Ecstasy Rees for 13

47

00:01:51,629 --> 00:01:57,000

years now January and July are generally

48

00:01:55,200 --> 00:02:00,509

the hardest months to get people to to

49

00:01:57,000 --> 00:02:02,879

come in and do the talk ok upcoming we

50

00:02:00,509 --> 00:02:04,140

do have other talks up coming next month

51

00:02:02,879 --> 00:02:06,839

February 3rd

52

00:02:04,140 --> 00:02:09,000

Jason Tomlinson has given me one longer

53

00:02:06,840 --> 00:02:12,569

talk longer talk titles I've ever been

54

00:02:09,000 --> 00:02:15,270

from cosmic birth to living earth the

55

00:02:12,569 --> 00:02:18,539

next great Space Telescope beyond jato

56

00:02:15,270 --> 00:02:20,370

is T and for those of you who know JWST

57

00:02:18,539 --> 00:02:22,650

stands for the James Webb Space

58
00:02:20,370 --> 00:02:23,700
Telescope and that's not launching till

59
00:02:22,650 --> 00:02:25,740
2018

60
00:02:23,699 --> 00:02:27,839
well Jason isn't satisfied with just

61
00:02:25,740 --> 00:02:30,420
looking forward a few years he's gonna

62
00:02:27,840 --> 00:02:32,460
look even beyond that to the telescopes

63
00:02:30,419 --> 00:02:36,479
that will come after the Webb telescope

64
00:02:32,460 --> 00:02:38,969
on March 3rd we have a very special

65
00:02:36,479 --> 00:02:43,099
event for you we have teamed with the

66
00:02:38,969 --> 00:02:46,199
Baltimore Museum of Art and they have a

67
00:02:43,099 --> 00:02:50,219
guest artist coming in Daria Robledo and

68
00:02:46,199 --> 00:02:53,789
in his exhibit he has several works

69
00:02:50,219 --> 00:02:56,789
inspired by Hubble and he will come and

70
00:02:53,789 --> 00:02:59,879
chat with some folks from here about the

71
00:02:56,789 --> 00:03:03,689
interplay of science and art on March

72
00:02:59,879 --> 00:03:05,810
3rd so that will be a lot of fun if you

73
00:03:03,689 --> 00:03:08,609
want to find out things on our web page

74
00:03:05,810 --> 00:03:11,729
we have this go link up here but as

75
00:03:08,610 --> 00:03:13,470
usual it's easiest if you just use your

76
00:03:11,729 --> 00:03:15,780
favorite search engine look for Hubble

77
00:03:13,469 --> 00:03:17,909
public talks and you should find this

78
00:03:15,780 --> 00:03:20,430
webpage you will have that has a list of

79
00:03:17,909 --> 00:03:22,469
the upcoming lectures information about

80
00:03:20,430 --> 00:03:25,230
other things and also if you see this

81
00:03:22,469 --> 00:03:28,500
link down here this is the archive to

82
00:03:25,229 --> 00:03:31,738
our lectures that have been webcast by

83
00:03:28,500 --> 00:03:34,500
our team here for the past decade we

84
00:03:31,739 --> 00:03:37,590
started doing this archive just before

85
00:03:34,500 --> 00:03:39,569
Hubble's 15th anniversary and so we are

86

00:03:37,590 --> 00:03:43,110
approaching our ten-year anniversary of

87
00:03:39,569 --> 00:03:45,299
webcasts so you've got ten years of cool

88
00:03:43,110 --> 00:03:46,920
talks to catch up on if you haven't been

89
00:03:45,299 --> 00:03:48,870
here before by the way I always like to

90
00:03:46,919 --> 00:03:51,958
ask every now and then alright how many

91
00:03:48,870 --> 00:03:54,719
people have not been here before wow

92
00:03:51,959 --> 00:03:56,849
that's a larger proportion than usual I

93
00:03:54,719 --> 00:03:59,039
guess the 25th anniversary got you got

94
00:03:56,849 --> 00:04:03,569
your attention cool

95
00:03:59,039 --> 00:04:07,079
great love to have that email if you

96
00:04:03,569 --> 00:04:09,689
would like announcements we have a email

97
00:04:07,080 --> 00:04:11,219
list that bike twice a month sends you

98
00:04:09,689 --> 00:04:14,099
an email reminding you of the upcoming

99
00:04:11,219 --> 00:04:16,319
lectures so far we've had a perfect

100
00:04:14,099 --> 00:04:17,699

record of no spam of course now that

101

00:04:16,319 --> 00:04:19,259

this is being webcast I know some

102

00:04:17,699 --> 00:04:22,108

hackers gonna go out there and find it

103

00:04:19,259 --> 00:04:23,099

and try and ruin that but so far we're

104

00:04:22,108 --> 00:04:25,409

just fine

105

00:04:23,100 --> 00:04:28,710

we have an email address public lecture

106

00:04:25,410 --> 00:04:31,199

at stsci edu which is the perfect place

107

00:04:28,709 --> 00:04:32,909

to send an email to sign up for these

108

00:04:31,199 --> 00:04:34,500

announcements because we'll have your

109

00:04:32,910 --> 00:04:37,620

email return address and can add you to

110

00:04:34,500 --> 00:04:41,370

the list you can also use this email for

111

00:04:37,620 --> 00:04:43,050

comments and/or questions now the one

112

00:04:41,370 --> 00:04:46,530

thing I don't know I'm sorry we have our

113

00:04:43,050 --> 00:04:49,560

social media on Facebook and Twitter and

114

00:04:46,529 --> 00:04:51,989

Google Plus and Pinterest and for me I

115
00:04:49,560 --> 00:04:55,259
have my Facebook and Google Plus and

116
00:04:51,990 --> 00:04:58,410
Twitter if you are so into following

117
00:04:55,259 --> 00:05:01,589
people in that way one thing I don't

118
00:04:58,410 --> 00:05:03,389
know is the observatory as the gentleman

119
00:05:01,589 --> 00:05:04,769
I did not get an email today telling me

120
00:05:03,389 --> 00:05:06,810
whether the observatory would be open

121
00:05:04,769 --> 00:05:08,728
tonight usually they are so this is a

122
00:05:06,810 --> 00:05:11,310
big question mark and has someone down

123
00:05:08,728 --> 00:05:13,019
the front row goes it's really cold but

124
00:05:11,310 --> 00:05:15,660
you know what the cold nights you get

125
00:05:13,019 --> 00:05:16,859
the best seeing okay this is one of the

126
00:05:15,660 --> 00:05:19,139
unfortunate things of being an

127
00:05:16,860 --> 00:05:23,340
astronomer when it's cold and the air is

128
00:05:19,139 --> 00:05:25,259
still you really get better seeing so I

129
00:05:23,339 --> 00:05:28,199
will ask again at the end of the lecture

130
00:05:25,259 --> 00:05:31,050
if there is somebody here to take you

131
00:05:28,199 --> 00:05:32,550
across otherwise you will be able to go

132
00:05:31,050 --> 00:05:34,410
home and have hot chocolate instead of

133
00:05:32,550 --> 00:05:36,660
going in freezing your Tootsie's off in

134
00:05:34,410 --> 00:05:38,160
the observatory dome but anyways thanks

135
00:05:36,660 --> 00:05:42,210
to the Maryland Space Grant Observatory

136
00:05:38,160 --> 00:05:44,340
for providing that every month ok so

137
00:05:42,209 --> 00:05:46,649
this is the point in the talk where I go

138
00:05:44,339 --> 00:05:50,089
to my news from the universe for January

139
00:05:46,649 --> 00:05:52,529
2015 and our top story for tonight is

140
00:05:50,089 --> 00:05:54,689
what are you kidding

141
00:05:52,529 --> 00:05:58,228
I'm doing the main talk and had no time

142
00:05:54,689 --> 00:06:02,639
to gather news stories which i think is

143

00:05:58,228 --> 00:06:12,269
pretty much self-explanatory so we move

144
00:06:02,639 --> 00:06:14,879
on to our featured speaker all right our

145
00:06:12,269 --> 00:06:19,430
featured speaker tonight is myself dr.

146
00:06:14,879 --> 00:06:19,430
Frank summers since we have some

147
00:06:22,839 --> 00:06:26,329
Thanks we have so many new people here

148
00:06:25,160 --> 00:06:28,939
tonight I'll give a little bit of my

149
00:06:26,329 --> 00:06:30,439
history I'm an astronomer who got his

150
00:06:28,939 --> 00:06:34,540
undergraduate degree at Virginia Tech

151
00:06:30,439 --> 00:06:37,120
Hokies and of his graduate degrees at

152
00:06:34,540 --> 00:06:39,530
University of California Berkeley I

153
00:06:37,120 --> 00:06:42,949
attended postdocs at Princeton and

154
00:06:39,529 --> 00:06:46,549
Columbia while I was at Columbia I also

155
00:06:42,949 --> 00:06:48,409
was working at the American Museum of

156
00:06:46,550 --> 00:06:50,780
Natural History in New York and I

157
00:06:48,410 --> 00:06:52,910

switched to full-time public outreach

158

00:06:50,779 --> 00:06:54,919

then one of the three curators that

159

00:06:52,910 --> 00:06:56,930

built the Rose Center for Earth and

160

00:06:54,920 --> 00:06:59,000

space in New York the home of the

161

00:06:56,930 --> 00:07:03,079

brand-new Hayden Planetarium in 2000

162

00:06:59,000 --> 00:07:04,519

after building the Rose Center I moved

163

00:07:03,079 --> 00:07:07,639

down here to Baltimore worked with

164

00:07:04,519 --> 00:07:09,620

Hubble and have been here for almost 14

165

00:07:07,639 --> 00:07:12,740

years I'm in the office of public

166

00:07:09,620 --> 00:07:15,980

outreach here and I get to work on all

167

00:07:12,740 --> 00:07:17,990

things Hubble it's really a great job I

168

00:07:15,980 --> 00:07:20,600

get to work in the news stories I get to

169

00:07:17,990 --> 00:07:22,400

work on the website I work on formal

170

00:07:20,600 --> 00:07:24,050

education doing teacher training and

171

00:07:22,399 --> 00:07:26,419

informal education with museums and

172
00:07:24,050 --> 00:07:28,329
planetariums and one of my specialties

173
00:07:26,420 --> 00:07:31,640
that I've developed while here is

174
00:07:28,329 --> 00:07:34,609
scientific visualization having worked

175
00:07:31,639 --> 00:07:37,039
on three IMAX films most notably being

176
00:07:34,610 --> 00:07:39,710
writer science advisor and scientific

177
00:07:37,040 --> 00:07:42,650
visualization supervisor on IMAX Hubble

178
00:07:39,709 --> 00:07:46,009
3d five years ago so ladies and

179
00:07:42,649 --> 00:07:48,859
gentlemen me Rory apologize I'll go do

180
00:07:46,009 --> 00:07:50,379
it again okay thank you thank you that

181
00:07:48,860 --> 00:07:56,150
wonderful and very knowledgeable

182
00:07:50,379 --> 00:08:00,050
introduction I have an impossible task

183
00:07:56,149 --> 00:08:04,159
I'm going to try to cover 25 years of

184
00:08:00,050 --> 00:08:05,329
Hubble in one lecture and as I was

185
00:08:04,160 --> 00:08:08,420
present getting this together

186
00:08:05,329 --> 00:08:11,060
I found all sorts of cool stuff that I

187
00:08:08,420 --> 00:08:13,699
can't include in this talk because I I

188
00:08:11,060 --> 00:08:15,889
spent this afternoon just hiding slides

189
00:08:13,699 --> 00:08:18,860
because there's so much really cool

190
00:08:15,889 --> 00:08:21,529
stuff so I want to say to those of you

191
00:08:18,860 --> 00:08:23,420
who have your favorite Hubble images the

192
00:08:21,529 --> 00:08:25,099
astronomers who might be watching who

193
00:08:23,420 --> 00:08:27,410
have their favourite Hubble observation

194
00:08:25,100 --> 00:08:30,290
probably because they were the PI on it

195
00:08:27,410 --> 00:08:31,180
and those of you who have this this this

196
00:08:30,290 --> 00:08:32,710
idea you're my

197
00:08:31,180 --> 00:08:34,990
just something that was just really

198
00:08:32,710 --> 00:08:38,050
struck you I may not include it in my

199
00:08:34,990 --> 00:08:40,120
talk tonight okay I have not decided on

200

00:08:38,049 --> 00:08:41,199
the best Hubble images I have not

201
00:08:40,120 --> 00:08:43,299
decided on the most scientifically

202
00:08:41,200 --> 00:08:46,990
important Hubble images I have decided

203
00:08:43,299 --> 00:08:49,479
on a suite of imagery that tells a story

204
00:08:46,990 --> 00:08:53,110
the story that I want to tell you about

205
00:08:49,480 --> 00:08:55,330
Hubble's 25 years okay so with that

206
00:08:53,110 --> 00:08:58,450
apology out of the way let's go for it

207
00:08:55,330 --> 00:09:01,360
now of course you can't do 25 years of

208
00:08:58,450 --> 00:09:04,540
Hubble without actually going back 70

209
00:09:01,360 --> 00:09:05,589
years 17 years to this man Lyman Spitzer

210
00:09:04,539 --> 00:09:09,009
and he was working at the RAND

211
00:09:05,589 --> 00:09:12,640
Corporation in 1946 and he wrote a white

212
00:09:09,009 --> 00:09:15,370
paper on the idea of a space telescope

213
00:09:12,639 --> 00:09:17,519
the benefits to astronomy of having a

214
00:09:15,370 --> 00:09:21,730

space telescope

215

00:09:17,519 --> 00:09:24,129

19:46 that was before we even had the

216

00:09:21,730 --> 00:09:26,560

space age the space age didn't come

217

00:09:24,129 --> 00:09:28,120

until a decade later with the beachball

218

00:09:26,559 --> 00:09:31,269

that was heard around the world

219

00:09:28,120 --> 00:09:32,528

Sputnik that orbited around and started

220

00:09:31,269 --> 00:09:34,809

the beginning of the Space Age

221

00:09:32,528 --> 00:09:38,169

well Sputnik orbiting around the world

222

00:09:34,809 --> 00:09:41,559

had stimulated a mission of the creation

223

00:09:38,169 --> 00:09:43,360

of NASA in 1958 the National Aeronautics

224

00:09:41,559 --> 00:09:45,789

and Space Administration this is their

225

00:09:43,360 --> 00:09:48,990

original logo this is their current

226

00:09:45,789 --> 00:09:53,079

current logo today created in 1958

227

00:09:48,990 --> 00:09:54,820

America gets into space well very soon

228

00:09:53,080 --> 00:09:57,879

thereafter the very beginning of the

229
00:09:54,820 --> 00:09:59,200
Space Age in 1962 this is the National

230
00:09:57,879 --> 00:10:03,009
Academy of Sciences Building in

231
00:09:59,200 --> 00:10:04,959
Washington DC it's just another you know

232
00:10:03,009 --> 00:10:06,759
ceremonial building in DC but it has

233
00:10:04,958 --> 00:10:08,799
this wonderful statue of Einstein out

234
00:10:06,759 --> 00:10:09,939
front so if your kids remember it they

235
00:10:08,799 --> 00:10:12,879
went out probably out and sat on

236
00:10:09,940 --> 00:10:13,959
Einsteins lap when they were there but

237
00:10:12,879 --> 00:10:16,629
the National Academy of Sciences

238
00:10:13,958 --> 00:10:18,458
convened a panel on discussing the

239
00:10:16,629 --> 00:10:22,450
benefits of what they called at the time

240
00:10:18,458 --> 00:10:25,088
a large Space Telescope recommended that

241
00:10:22,450 --> 00:10:28,660
America should move forward on putting a

242
00:10:25,089 --> 00:10:30,839
large telescope into space this of

243

00:10:28,659 --> 00:10:34,439

course ignited all sorts of ideas

244

00:10:30,839 --> 00:10:37,990

everybody has their wonderful ideas and

245

00:10:34,440 --> 00:10:39,279

astronomers are great people but I gotta

246

00:10:37,990 --> 00:10:40,570

say astronomers tend to think that

247

00:10:39,278 --> 00:10:43,269

they're the smartest person in the room

248

00:10:40,570 --> 00:10:44,440

so they tend to want to have their idea

249

00:10:43,269 --> 00:10:45,789

go forward and this

250

00:10:44,440 --> 00:10:48,370

haven't one have their idea horse

251

00:10:45,789 --> 00:10:51,250

there's lots and lots of various ideas

252

00:10:48,370 --> 00:10:53,080

various competing ideas and not just in

253

00:10:51,250 --> 00:10:57,429

the US but around the world

254

00:10:53,080 --> 00:10:59,500

well the logjam was broken in 1976 when

255

00:10:57,429 --> 00:11:02,529

NASA which by now had moved on to this

256

00:10:59,500 --> 00:11:04,929

wonderful worm logo and Issa the

257

00:11:02,529 --> 00:11:06,490
European Space Administration decided

258
00:11:04,929 --> 00:11:09,429
they were going to do a joint proposal

259
00:11:06,490 --> 00:11:12,159
together they pulled their ideas

260
00:11:09,429 --> 00:11:14,829
together and that is what broke the

261
00:11:12,159 --> 00:11:18,909
logjam that's what enabled enough

262
00:11:14,830 --> 00:11:23,379
political will to get Congress to fund

263
00:11:18,909 --> 00:11:25,299
the large Space Telescope in 1977 well

264
00:11:23,379 --> 00:11:26,919
now that you've got funding in a plan

265
00:11:25,299 --> 00:11:30,909
and it moves it moves forward very

266
00:11:26,919 --> 00:11:34,269
quickly in the 1980's the telescope was

267
00:11:30,909 --> 00:11:37,179
built in 1985 it was completed and

268
00:11:34,269 --> 00:11:39,549
construction here it is in Sunnyvale

269
00:11:37,179 --> 00:11:41,289
California and what is happening is it's

270
00:11:39,549 --> 00:11:43,779
undergoing a shake test here here's the

271
00:11:41,289 --> 00:11:46,120

guy in the bunny suit for scale so this

272

00:11:43,779 --> 00:11:49,230

is a human size and this is the size of

273

00:11:46,120 --> 00:11:52,210

the Hubble Space Telescope it was

274

00:11:49,230 --> 00:11:54,269

certified for launch and it was ready to

275

00:11:52,210 --> 00:11:57,460

go up on the space shuttle

276

00:11:54,269 --> 00:11:59,799

unfortunately in 1986 we had the

277

00:11:57,460 --> 00:12:01,900

Challenger accident the space shuttle

278

00:11:59,799 --> 00:12:06,099

program was grounded for several years

279

00:12:01,899 --> 00:12:10,120

and Hubble sat in storage waiting to go

280

00:12:06,100 --> 00:12:11,920

up finally in 1990 Hubble did launch

281

00:12:10,120 --> 00:12:13,830

this is the launch of the Hubble Space

282

00:12:11,919 --> 00:12:17,049

Telescope you'll notice there's another

283

00:12:13,830 --> 00:12:18,370

shuttle on the launch pad here that we

284

00:12:17,049 --> 00:12:20,559

were they were doing some testing there

285

00:12:18,370 --> 00:12:21,700

is only a few times when in the history

286
00:12:20,559 --> 00:12:23,859
of the shuttle program when there have

287
00:12:21,700 --> 00:12:25,509
been two shuttles on the launch pad they

288
00:12:23,860 --> 00:12:29,080
were doing testing here while they

289
00:12:25,509 --> 00:12:33,100
launched Hubble here here as the

290
00:12:29,080 --> 00:12:34,720
wonderful astronaut team that put Hubble

291
00:12:33,100 --> 00:12:36,700
into space you will notice this

292
00:12:34,720 --> 00:12:37,740
gentleman right here does anybody know

293
00:12:36,700 --> 00:12:41,440
who he is

294
00:12:37,740 --> 00:12:45,879
that's Charlie Bolden the current NASA

295
00:12:41,440 --> 00:12:48,730
Administrator he put Hubble into orbit

296
00:12:45,879 --> 00:12:52,000
so we like that we hope that that made

297
00:12:48,730 --> 00:12:53,860
him fond of our telescope here is the

298
00:12:52,000 --> 00:12:56,230
telescope sitting in the shuttle payload

299
00:12:53,860 --> 00:12:58,029
Bay you will notice that it fits very

300
00:12:56,230 --> 00:13:00,580
nicely in the shuttle payload Bay

301
00:12:58,029 --> 00:13:02,230
and that is of course by design simply

302
00:13:00,580 --> 00:13:04,450
because we couldn't make Hubble any

303
00:13:02,230 --> 00:13:06,940
larger than what would fit in the

304
00:13:04,450 --> 00:13:09,250
shuttle payload Bay okay would we have

305
00:13:06,940 --> 00:13:12,010
liked an even larger telescope of course

306
00:13:09,250 --> 00:13:13,690
we would were astronomers and bigger is

307
00:13:12,009 --> 00:13:15,850
better and when it comes to mirrors and

308
00:13:13,690 --> 00:13:17,440
everything but we had a limitation it's

309
00:13:15,850 --> 00:13:19,149
always good to have limitations our

310
00:13:17,440 --> 00:13:21,250
limitation was the size of the shuttle

311
00:13:19,149 --> 00:13:24,549
payload Bay the shuttle payload they

312
00:13:21,250 --> 00:13:26,649
also carried aboard an IMAX camera and

313
00:13:24,549 --> 00:13:29,889
it got this IMAX camera got this amazing

314

00:13:26,649 --> 00:13:36,159
shot of Hubble being set into orbit on

315
00:13:29,889 --> 00:13:40,449
April 25th 1990 so Hubble is finally up

316
00:13:36,159 --> 00:13:42,870
there from 1946 to 1990 that's all the

317
00:13:40,450 --> 00:13:47,650
precursor history to get Hubble launched

318
00:13:42,870 --> 00:13:53,169
well what do you happens first we get

319
00:13:47,649 --> 00:13:54,220
stories like this NASA's 1.5 billion

320
00:13:53,169 --> 00:13:55,959
blunder

321
00:13:54,220 --> 00:13:59,860
we've got Hubble with a character of mr.

322
00:13:55,960 --> 00:14:02,200
Magoo on even xkcd which is a very geeky

323
00:13:59,860 --> 00:14:04,930
comic strip said Edwin Hubble's car

324
00:14:02,200 --> 00:14:06,820
objects in mirror are something's blur

325
00:14:04,929 --> 00:14:12,789
than they appear or something at that I

326
00:14:06,820 --> 00:14:16,500
can't quite read that so well Hubble's

327
00:14:12,789 --> 00:14:19,779
mirror was ground to a very exact shape

328
00:14:16,500 --> 00:14:22,480

but it was slightly off okay

329

00:14:19,779 --> 00:14:25,720

Hubble after all this precursor history

330

00:14:22,480 --> 00:14:27,670

had a flaw alright and if the flaw was

331

00:14:25,720 --> 00:14:29,350

actually not in the grinding but in the

332

00:14:27,669 --> 00:14:31,539

testing apparatus for the grinding

333

00:14:29,350 --> 00:14:32,680

because from what I understand there

334

00:14:31,539 --> 00:14:35,289

were some pins that were supposed to

335

00:14:32,679 --> 00:14:37,809

drop down into slots for the testing

336

00:14:35,289 --> 00:14:39,699

apparatus and one pin got hooked up a

337

00:14:37,809 --> 00:14:42,729

little bit and so the testing apparatus

338

00:14:39,700 --> 00:14:45,250

was slightly out of shape the testing

339

00:14:42,730 --> 00:14:48,339

apparatus was telling the mirror

340

00:14:45,250 --> 00:14:51,220

polishing to grind it to a very exact

341

00:14:48,339 --> 00:14:53,620

shape but just slightly wrong what did

342

00:14:51,220 --> 00:14:55,839

that mean in practice well it meant that

343
00:14:53,620 --> 00:14:58,089
a star which is supposed to be a point

344
00:14:55,839 --> 00:15:00,430
of light ended up having all this

345
00:14:58,089 --> 00:15:02,980
scattered light around it okay

346
00:15:00,429 --> 00:15:07,000
so Hubble wasn't doing what it was

347
00:15:02,980 --> 00:15:10,539
supposed to but that does not mean it

348
00:15:07,000 --> 00:15:11,559
was the mr. Magoo of telescopes okay all

349
00:15:10,539 --> 00:15:13,329
of those cartoon

350
00:15:11,559 --> 00:15:16,209
all of the things on Johnny Carson at

351
00:15:13,330 --> 00:15:18,460
the time overstated it because Hubble

352
00:15:16,210 --> 00:15:20,740
could still do better things than we

353
00:15:18,460 --> 00:15:23,200
could do from the ground for example

354
00:15:20,740 --> 00:15:25,570
this is an image of a double star from

355
00:15:23,200 --> 00:15:26,830
the ground and any astronomer who looks

356
00:15:25,570 --> 00:15:29,800
at that will tell you the yeah that's a

357
00:15:26,830 --> 00:15:32,470
double star why because if it were a

358
00:15:29,799 --> 00:15:35,620
single star it would be a circle it is

359
00:15:32,470 --> 00:15:39,220
an oval so there must be two sources in

360
00:15:35,620 --> 00:15:43,169
there to create that oval shape Hubble

361
00:15:39,220 --> 00:15:46,420
with the flaw could see it like that

362
00:15:43,169 --> 00:15:48,039
okay now those stars aren't perfect

363
00:15:46,419 --> 00:15:51,669
pinpoints of light like what we like

364
00:15:48,039 --> 00:15:55,509
them to but we can still do science with

365
00:15:51,669 --> 00:15:57,879
the flaw in Hubble's mirror so what did

366
00:15:55,509 --> 00:15:59,620
we do here's another example from the

367
00:15:57,879 --> 00:16:01,720
ground this is what Pluto and Charon

368
00:15:59,620 --> 00:16:03,519
looked at looked like by the way you got

369
00:16:01,720 --> 00:16:07,960
to remember that Karen had only been

370
00:16:03,519 --> 00:16:09,460
discovered in the 1980s okay maybe

371

00:16:07,960 --> 00:16:11,320
people don't remember that Karen was

372
00:16:09,460 --> 00:16:13,360
only discovered in the 1980s this was

373
00:16:11,320 --> 00:16:15,580
brand-new from the ground you could see

374
00:16:13,360 --> 00:16:17,889
there's Pluto and there's Karen with

375
00:16:15,580 --> 00:16:21,280
Hubble you can easily distinguish them

376
00:16:17,889 --> 00:16:23,769
very clearly you can still do things

377
00:16:21,279 --> 00:16:26,049
that not capable from the ground we

378
00:16:23,769 --> 00:16:28,329
could also watch other things okay so

379
00:16:26,049 --> 00:16:32,349
some of the science stories in 1991

380
00:16:28,330 --> 00:16:34,270
there was a major storm on Saturn now

381
00:16:32,350 --> 00:16:35,740
we're used to having Jupiter having lots

382
00:16:34,269 --> 00:16:37,750
of storms we know about the Great Red

383
00:16:35,740 --> 00:16:40,000
Spot and all the storms on Jupiter but

384
00:16:37,750 --> 00:16:43,089
this is Saturn and it only has storms

385
00:16:40,000 --> 00:16:44,559

like this in decades along cycle matter

386

00:16:43,089 --> 00:16:47,440

of fact they tell me the Lord the Lord

387

00:16:44,559 --> 00:16:48,729

the the large storm before this was in

388

00:16:47,440 --> 00:16:51,370

1933

389

00:16:48,730 --> 00:16:53,800

so having Hubble up there to be able to

390

00:16:51,370 --> 00:16:55,240

see it was absolutely amazing this is a

391

00:16:53,799 --> 00:16:59,740

storm that actually stretched all the

392

00:16:55,240 --> 00:17:02,259

way around the planet 1991 we also

393

00:16:59,740 --> 00:17:05,380

showed off Hubble's ability to use fine

394

00:17:02,259 --> 00:17:07,809

resolution to look into star clusters

395

00:17:05,380 --> 00:17:09,490

called globular clusters now in this

396

00:17:07,809 --> 00:17:10,899

ground-based image here you can see that

397

00:17:09,490 --> 00:17:14,109

the core of the globular cluster

398

00:17:10,900 --> 00:17:16,780

Scoville coaster called 47 Tucanae is

399

00:17:14,109 --> 00:17:18,369

basically blown out usually it is so

400
00:17:16,779 --> 00:17:21,220
dense in the cores of these clusters

401
00:17:18,369 --> 00:17:23,799
that from the ground all the stars in

402
00:17:21,220 --> 00:17:25,328
the center are smeared together Hubble

403
00:17:23,799 --> 00:17:28,509
with its fine resolution

404
00:17:25,328 --> 00:17:31,808
can resolve the individual stars and

405
00:17:28,509 --> 00:17:34,839
what it found was a population of stars

406
00:17:31,808 --> 00:17:36,908
we call blue stragglers stars that

407
00:17:34,839 --> 00:17:39,069
because their age should appear much

408
00:17:36,909 --> 00:17:41,619
redder but for some reason they're they

409
00:17:39,069 --> 00:17:44,618
appeared bluer which is younger than

410
00:17:41,618 --> 00:17:47,408
they should have indicating that there

411
00:17:44,618 --> 00:17:50,288
probably were stellar collisions going

412
00:17:47,409 --> 00:17:52,269
on in globular clusters now stars are

413
00:17:50,288 --> 00:17:54,519
just so far apart they never come

414
00:17:52,269 --> 00:17:56,618
anywhere near each other except in the

415
00:17:54,519 --> 00:17:59,440
incredibly dense environments of these

416
00:17:56,618 --> 00:18:02,709
globular clusters showing that you can

417
00:17:59,440 --> 00:18:07,509
actually get two stars colliding in the

418
00:18:02,710 --> 00:18:10,379
cores uncle Aubrey our clusters 1992 we

419
00:18:07,509 --> 00:18:12,878
looked at this galaxy Messier 87 and

420
00:18:10,378 --> 00:18:15,308
Messier 87 is a giant elliptical galaxy

421
00:18:12,878 --> 00:18:17,980
in the center of the Virgo cluster and

422
00:18:15,308 --> 00:18:20,558
you can see that it has a bright source

423
00:18:17,980 --> 00:18:23,679
in the center this is a super massive

424
00:18:20,558 --> 00:18:25,538
black hole supermassive black hole with

425
00:18:23,679 --> 00:18:28,179
approximately a billion times the mass

426
00:18:25,538 --> 00:18:31,569
of our Sun and it's outputting in an

427
00:18:28,179 --> 00:18:35,139
energetic jeta streaming cross inner

428

00:18:31,569 --> 00:18:38,950
stellar space and the details of this

429
00:18:35,138 --> 00:18:41,888
jet were revealed by Hubble in 1992 and

430
00:18:38,950 --> 00:18:44,470
in ways that you could not see from the

431
00:18:41,888 --> 00:18:46,418
ground I am a hammering home that we can

432
00:18:44,470 --> 00:18:48,339
still do good science and those first

433
00:18:46,419 --> 00:18:52,859
tertiary we did do great science in

434
00:18:48,339 --> 00:18:55,238
those first three years also in 1993

435
00:18:52,858 --> 00:18:57,249
amazing thing that I only fully

436
00:18:55,239 --> 00:18:58,778
appreciated when I started when I

437
00:18:57,249 --> 00:19:02,079
studied for this talk

438
00:18:58,778 --> 00:19:03,730
looking at the Andromeda galaxy in the

439
00:19:02,079 --> 00:19:05,168
core of it in the Andromeda galaxy if

440
00:19:03,730 --> 00:19:08,200
you look way down on the core you can

441
00:19:05,169 --> 00:19:11,350
see the center of Andromeda except for

442
00:19:08,200 --> 00:19:13,869

from the ground you are fooled that is

443

00:19:11,349 --> 00:19:16,599

not the core of Andromeda when we

444

00:19:13,868 --> 00:19:19,019

studied it with Hubble we could see that

445

00:19:16,599 --> 00:19:21,459

there are actually two cores in the

446

00:19:19,019 --> 00:19:23,138

Andromeda galaxy and what we had

447

00:19:21,460 --> 00:19:26,619

previously thought was the core of

448

00:19:23,138 --> 00:19:28,928

Andromeda is really a star cluster near

449

00:19:26,618 --> 00:19:31,358

the center of Andromeda and the center

450

00:19:28,929 --> 00:19:34,210

of Andromeda is actually this lighter

451

00:19:31,358 --> 00:19:35,858

spot over here on the right with

452

00:19:34,210 --> 00:19:37,220

Hubble's resolution were able to see

453

00:19:35,858 --> 00:19:40,419

into the

454

00:19:37,220 --> 00:19:42,589

of that galaxy and find find where the

455

00:19:40,420 --> 00:19:45,039

actually we expect a supermassive black

456

00:19:42,589 --> 00:19:47,509

hole will be in the core of that galaxy

457
00:19:45,039 --> 00:19:49,369
Hubble did a lot of work in its early

458
00:19:47,509 --> 00:19:52,099
years studying the Centers of galaxies

459
00:19:49,369 --> 00:19:54,289
looking for telltale evidence of these

460
00:19:52,099 --> 00:19:56,089
supermassive black holes and basically

461
00:19:54,289 --> 00:19:59,029
the answer is we found a supermassive

462
00:19:56,089 --> 00:20:03,259
black hole in every large galaxy that we

463
00:19:59,029 --> 00:20:07,099
looked at also in 1993 we had this

464
00:20:03,259 --> 00:20:10,490
wonderful image of a comet this is comet

465
00:20:07,099 --> 00:20:13,519
shoemaker-levy 9 which was discovered in

466
00:20:10,490 --> 00:20:17,120
1993 and it was in orbit around Jupiter

467
00:20:13,519 --> 00:20:20,690
and it had broken up into many different

468
00:20:17,119 --> 00:20:23,169
pieces the prediction was that

469
00:20:20,690 --> 00:20:27,680
shoemaker-levy 9 was going to strike

470
00:20:23,170 --> 00:20:30,650
Jupiter but first Hubble got its repair

471
00:20:27,680 --> 00:20:32,870
mission late 1993 this group of

472
00:20:30,650 --> 00:20:36,230
astronauts went up on the space shuttle

473
00:20:32,869 --> 00:20:39,250
to service the service Hubble what they

474
00:20:36,230 --> 00:20:43,190
did is they added in glasses to correct

475
00:20:39,250 --> 00:20:45,049
the flaw in the mirror now optics

476
00:20:43,190 --> 00:20:46,700
they've learned a lot of things in life

477
00:20:45,049 --> 00:20:47,180
for say oh it's not really an exact

478
00:20:46,700 --> 00:20:50,180
science

479
00:20:47,180 --> 00:20:53,390
well optics really is an exact science

480
00:20:50,180 --> 00:20:56,029
so we knew the shape that Hubble's

481
00:20:53,390 --> 00:20:58,730
mirror had been ground to and we knew

482
00:20:56,029 --> 00:21:02,480
the shape we really wanted so we can

483
00:20:58,730 --> 00:21:04,970
design an exact corrector plate to put

484
00:21:02,480 --> 00:21:09,769
in the what pathway think of it as some

485

00:21:04,970 --> 00:21:11,390
eyeglasses to correct for that now we

486
00:21:09,769 --> 00:21:14,480
put in an instrument called co-star

487
00:21:11,390 --> 00:21:16,970
corrective optics space telescope axial

488
00:21:14,480 --> 00:21:20,059
replacement quite a convoluted acronym

489
00:21:16,970 --> 00:21:22,309
but you know it worked to put to correct

490
00:21:20,059 --> 00:21:25,069
the optics for the instruments that were

491
00:21:22,309 --> 00:21:27,319
already installed and this here is what

492
00:21:25,069 --> 00:21:30,409
wide field planetary camera one that's

493
00:21:27,319 --> 00:21:33,079
being taken out and we put in wide field

494
00:21:30,410 --> 00:21:35,540
planetary camera 2 which had the

495
00:21:33,079 --> 00:21:37,819
correction already applied so it didn't

496
00:21:35,539 --> 00:21:39,409
need any high glasses now you got to

497
00:21:37,819 --> 00:21:41,659
recognize that when we're looking at

498
00:21:39,410 --> 00:21:44,210
these wavelengths we're trying to get

499
00:21:41,660 --> 00:21:45,620

down to a tenth at least in a way like

500

00:21:44,210 --> 00:21:47,720

maybe even 100 the way like we're

501

00:21:45,619 --> 00:21:50,989

talking you know 10 nanometer scales

502

00:21:47,720 --> 00:21:53,690

that you have to position these optics

503

00:21:50,990 --> 00:21:56,299

and frankly I'm not an engineer I'm not

504

00:21:53,690 --> 00:21:57,769

an optical optical guy I was kind of

505

00:21:56,299 --> 00:22:03,740

unsure as to whether this would really

506

00:21:57,769 --> 00:22:06,289

work well it did here is the view of a

507

00:22:03,740 --> 00:22:11,870

star before co-star was installed and

508

00:22:06,289 --> 00:22:14,000

after co-star boom they did it okay I

509

00:22:11,869 --> 00:22:16,939

wasn't here at Hubbell at the time but

510

00:22:14,000 --> 00:22:19,369

they really nailed it they got that

511

00:22:16,940 --> 00:22:22,910

point of light of a star that was

512

00:22:19,369 --> 00:22:25,759

expected Hubble net its design

513

00:22:22,910 --> 00:22:28,058

specification and now could start doing

514
00:22:25,759 --> 00:22:32,690
the science it was intended in

515
00:22:28,058 --> 00:22:34,879
particular the imagery the imagery is

516
00:22:32,690 --> 00:22:37,190
what really show what really was gonna

517
00:22:34,880 --> 00:22:41,179
attract your attention here is the core

518
00:22:37,190 --> 00:22:47,019
of the galaxy m100 in after from with

519
00:22:41,179 --> 00:22:51,170
pick one when we add in the new one boom

520
00:22:47,019 --> 00:22:54,170
quite a difference now Hubble is up to

521
00:22:51,170 --> 00:22:56,630
its full capability we can go back to

522
00:22:54,170 --> 00:22:59,029
looking at Comet shoemaker-levy 9 this

523
00:22:56,630 --> 00:23:02,179
is an image of those pieces of Comet

524
00:22:59,029 --> 00:23:03,799
shoemaker-levy 9 1994 with the repaired

525
00:23:02,179 --> 00:23:06,050
instruments and you can see it's much

526
00:23:03,799 --> 00:23:09,379
clearer but what we really wanted to see

527
00:23:06,049 --> 00:23:13,099
was it was gonna smash into Jupiter now

528
00:23:09,380 --> 00:23:15,500
let's think about it these comet pieces

529
00:23:13,099 --> 00:23:16,959
are like one or maybe two kilometers

530
00:23:15,500 --> 00:23:20,839
across

531
00:23:16,960 --> 00:23:24,529
Jupiter is a hundred and forty thousand

532
00:23:20,839 --> 00:23:27,970
kilometers across two kilometers a

533
00:23:24,529 --> 00:23:31,399
hundred and forty thousand kilometers

534
00:23:27,970 --> 00:23:34,000
it's a pinprick right nothing's gonna

535
00:23:31,400 --> 00:23:37,280
happen it was all sorts of debate but

536
00:23:34,000 --> 00:23:39,740
fortunately Hubble was looking because

537
00:23:37,279 --> 00:23:42,470
something did happen and here's what

538
00:23:39,740 --> 00:23:44,799
Hubble saw in visible light this is

539
00:23:42,470 --> 00:23:48,049
Jupiter and you see these black marks

540
00:23:44,799 --> 00:23:50,450
these are the impact sets where these

541
00:23:48,049 --> 00:23:52,009
fragments of comets smashed into

542

00:23:50,450 --> 00:23:55,460
Jupiter's atmosphere and basically

543
00:23:52,009 --> 00:23:58,400
exploded and created huge holes in

544
00:23:55,460 --> 00:24:00,890
Jupiter's atmosphere every telescope in

545
00:23:58,400 --> 00:24:03,350
the world was watching but only Hubble

546
00:24:00,890 --> 00:24:04,669
was above Earth's atmosphere and could

547
00:24:03,349 --> 00:24:07,368
also watch

548
00:24:04,669 --> 00:24:10,340
in ultraviolet light where you can see

549
00:24:07,368 --> 00:24:11,628
the impact sites much more clearly by

550
00:24:10,339 --> 00:24:14,178
the way this is not an impact site

551
00:24:11,628 --> 00:24:16,459
that's just a shadow of a moon okay one

552
00:24:14,179 --> 00:24:18,499
of the Galilean moons so you could an

553
00:24:16,460 --> 00:24:20,149
ultraviolet light I know you all think

554
00:24:18,499 --> 00:24:21,319
that when you go out in the summer you

555
00:24:20,148 --> 00:24:22,969
have to put on the suntan lotion because

556
00:24:21,319 --> 00:24:25,759

lots of ultraviolet light is out is

557

00:24:22,970 --> 00:24:27,019

coming down almost no volts or violet

558

00:24:25,759 --> 00:24:31,179

light gets through our atmosphere in

559

00:24:27,019 --> 00:24:31,179

reality okay to do ultralinks

560

00:24:38,569 --> 00:24:46,668

in terms of seeing the observations of

561

00:24:41,388 --> 00:24:48,589

Comet shoemaker-levy 9 1995 and right

562

00:24:46,669 --> 00:24:51,710

out of the gate we're gonna hit one of

563

00:24:48,589 --> 00:24:53,988

our best images ever this is the

564

00:24:51,710 --> 00:24:57,319

so-called pillars of creation the

565

00:24:53,989 --> 00:25:00,350

pillars in the Eagle Nebula and to this

566

00:24:57,319 --> 00:25:04,099

day it is one of our most popular images

567

00:25:00,349 --> 00:25:06,998

if not the most popular I gotta say the

568

00:25:04,099 --> 00:25:09,678

public just loves ionization fronts ok

569

00:25:06,999 --> 00:25:13,879

what is an ionization front you ask well

570

00:25:09,679 --> 00:25:15,259

I'll answer that so up there a couple

571
00:25:13,878 --> 00:25:17,569
floors above us there are some really

572
00:25:15,259 --> 00:25:20,839
really bright stars and they have

573
00:25:17,569 --> 00:25:23,898
high-energy radiation and stellar winds

574
00:25:20,839 --> 00:25:25,308
streaming away from them that energy is

575
00:25:23,898 --> 00:25:27,949
coming down like this

576
00:25:25,308 --> 00:25:29,690
hitting these dense regions at the tops

577
00:25:27,950 --> 00:25:32,119
of the pillars and you can see the

578
00:25:29,690 --> 00:25:34,639
bright light around them as it takes

579
00:25:32,118 --> 00:25:37,189
that dark gas dense gas this molecular

580
00:25:34,638 --> 00:25:40,038
gas and ionizes it the energy is

581
00:25:37,190 --> 00:25:42,489
transferred to that dark gas and it

582
00:25:40,038 --> 00:25:45,288
ionizes and you create these pillars

583
00:25:42,489 --> 00:25:48,288
because the winds are streaming down and

584
00:25:45,288 --> 00:25:51,408
in here it's not necessarily dense gas

585
00:25:48,288 --> 00:25:54,470
it is just in the shadow of these dense

586
00:25:51,409 --> 00:25:56,929
regions at the tops of the pillars and

587
00:25:54,470 --> 00:25:59,419
creates this great silhouette that's

588
00:25:56,929 --> 00:26:04,909
great contrast against the background of

589
00:25:59,419 --> 00:26:06,919
the image of the nebula also in 1995 the

590
00:26:04,909 --> 00:26:08,899
exact matter fact two weeks after that

591
00:26:06,919 --> 00:26:11,090
image was released another of our

592
00:26:08,898 --> 00:26:13,608
amazing images was released this one of

593
00:26:11,089 --> 00:26:16,158
the trapezium region in the Orion Nebula

594
00:26:13,608 --> 00:26:17,278
center of the Orion Nebula another star

595
00:26:16,159 --> 00:26:19,559
forming Reed

596
00:26:17,278 --> 00:26:22,589
and in the Orion Nebula there are

597
00:26:19,558 --> 00:26:25,079
thousands of new stars being born and

598
00:26:22,589 --> 00:26:27,538
plus the center stars and here are also

599

00:26:25,079 --> 00:26:30,990
blowing off their winds such that this

600
00:26:27,538 --> 00:26:33,000
object down here LLO or yonus you can

601
00:26:30,990 --> 00:26:34,829
see has a bow shock around it the wind

602
00:26:33,000 --> 00:26:38,038
coming down from these bright stars

603
00:26:34,829 --> 00:26:40,439
creates a bow shock around it someone in

604
00:26:38,038 --> 00:26:41,819
right close to the trapezium stars you

605
00:26:40,440 --> 00:26:45,000
can see that the bow shock is wrapped

606
00:26:41,819 --> 00:26:47,158
around to make a tadpole alright this is

607
00:26:45,000 --> 00:26:49,589
the wind streaming past the material

608
00:26:47,159 --> 00:26:52,649
around this forming solar forming star

609
00:26:49,589 --> 00:26:55,589
creating a sort of wind sock effect and

610
00:26:52,648 --> 00:26:58,918
what's really cool is that if you look

611
00:26:55,589 --> 00:27:02,819
in detail you can see these dust disks

612
00:26:58,919 --> 00:27:06,960
around brand-new stars and these dusty

613
00:27:02,819 --> 00:27:10,259

discs are where the planets are forming

614

00:27:06,960 --> 00:27:14,490

in a new solar system within the Orion

615

00:27:10,259 --> 00:27:18,329

Nebula we get to see other solar systems

616

00:27:14,490 --> 00:27:19,230

in formation and Hubble was the first to

617

00:27:18,329 --> 00:27:22,558

be able to give us the kind of

618

00:27:19,230 --> 00:27:27,028

resolution to see this amazing detail

619

00:27:22,558 --> 00:27:30,480

here 1996 we go from star birth to star

620

00:27:27,028 --> 00:27:33,269

death this is the star eita Carina and

621

00:27:30,480 --> 00:27:36,298

it is a hundred solar mass star maybe

622

00:27:33,269 --> 00:27:39,419

150 solar mass star and it is not just

623

00:27:36,298 --> 00:27:42,000

being born but instead we believe it's

624

00:27:39,419 --> 00:27:44,580

on its way to die this is what we

625

00:27:42,000 --> 00:27:46,679

consider to be a pre supernova star a

626

00:27:44,579 --> 00:27:49,798

star at the end of its life that we

627

00:27:46,679 --> 00:27:51,990

expect to explode sometime in the next

628
00:27:49,798 --> 00:27:54,329
few million years but what we can see

629
00:27:51,990 --> 00:27:56,220
here is an amazing detail of what's

630
00:27:54,329 --> 00:27:58,769
called the homunculus these big lobes

631
00:27:56,220 --> 00:28:00,630
these bubbles the stars in the center

632
00:27:58,769 --> 00:28:02,460
here you can see this incredible bubble

633
00:28:00,630 --> 00:28:05,278
being blown from both directions these

634
00:28:02,460 --> 00:28:08,850
bipolar bubbles and then outbursts from

635
00:28:05,278 --> 00:28:10,308
a tack are going out and again detail

636
00:28:08,849 --> 00:28:13,349
that we had never seen before

637
00:28:10,308 --> 00:28:18,048
we also in seeing amazing detail

638
00:28:13,349 --> 00:28:20,038
measured the first size of a star now

639
00:28:18,048 --> 00:28:21,690
you may think about this all right well

640
00:28:20,038 --> 00:28:24,028
we can see the Sun and it's it's a half

641
00:28:21,690 --> 00:28:25,740
a degree across okay so you know we can

642
00:28:24,028 --> 00:28:30,269
see the size of that star but every

643
00:28:25,740 --> 00:28:30,710
other star is so far away it appears as

644
00:28:30,269 --> 00:28:32,980
a

645
00:28:30,710 --> 00:28:36,259
of light even in our best telescopes

646
00:28:32,980 --> 00:28:39,259
well with Hubble we're able to make out

647
00:28:36,259 --> 00:28:42,048
the size of baitul juice this is the

648
00:28:39,259 --> 00:28:47,028
shoulder of Orion here it is a red

649
00:28:42,048 --> 00:28:50,298
supergiant star that is so large that if

650
00:28:47,028 --> 00:28:53,269
it were in our solar system it would be

651
00:28:50,298 --> 00:28:56,058
larger than Earth's orbit it would be

652
00:28:53,269 --> 00:29:00,079
larger than Jupiter's orbit Mercury

653
00:28:56,058 --> 00:29:02,918
Venus Earth Mars the asteroid belt and

654
00:29:00,079 --> 00:29:06,079
Jupiter would all be orbiting inside

655
00:29:02,919 --> 00:29:08,450
fatal juice were where our son is

656

00:29:06,079 --> 00:29:12,220
and with Hubble we're able to measure

657
00:29:08,450 --> 00:29:16,069
the size of that star the first one ever

658
00:29:12,220 --> 00:29:18,409
well 1997 brought servicing mission two

659
00:29:16,069 --> 00:29:20,418
and this is the amazing crew that went

660
00:29:18,409 --> 00:29:24,020
up to service Hubble on the second

661
00:29:20,419 --> 00:29:26,330
servicing mission servicing mission two

662
00:29:24,019 --> 00:29:27,619
added in two new instruments the near

663
00:29:26,329 --> 00:29:29,928
infrared camera multi-object

664
00:29:27,619 --> 00:29:31,369
spectrograph otherwise known as Nick

665
00:29:29,929 --> 00:29:33,740
Moss which added to the infrared

666
00:29:31,369 --> 00:29:36,408
capabilities of Hubble and the Space

667
00:29:33,740 --> 00:29:38,659
Telescope imaging spectrograph which

668
00:29:36,409 --> 00:29:42,169
both of them are spectrum spectrographs

669
00:29:38,659 --> 00:29:45,520
but they also add to this adds to the

670
00:29:42,169 --> 00:29:49,610

ultraviolet capabilities of Hubble that

671

00:29:45,519 --> 00:29:52,429

mission again was success and this may

672

00:29:49,609 --> 00:29:54,648

look to you like a picture of Mars it's

673

00:29:52,429 --> 00:29:57,259

not this is something I discovered

674

00:29:54,648 --> 00:29:58,969

actually this morning as I was going

675

00:29:57,259 --> 00:30:01,069

through making sure I had all the really

676

00:29:58,970 --> 00:30:03,190

cool images this is one I didn't know

677

00:30:01,069 --> 00:30:08,148

about this is not Mars

678

00:30:03,190 --> 00:30:10,909

this is Jupiter's moon Io and what you

679

00:30:08,148 --> 00:30:13,849

see on the limb of Jupiter's moon looks

680

00:30:10,909 --> 00:30:16,570

like a blurry thing which is just an

681

00:30:13,849 --> 00:30:19,398

error right no it's not

682

00:30:16,569 --> 00:30:22,220

Jupiter's moon Io is the most volcanic

683

00:30:19,398 --> 00:30:24,619

object in the solar system there are an

684

00:30:22,220 --> 00:30:28,069

average of seven volcanoes going off at

685
00:30:24,619 --> 00:30:31,038
any one time and the volcanic plumes

686
00:30:28,069 --> 00:30:36,230
reach so high they can actually be seen

687
00:30:31,038 --> 00:30:39,408
off the limb of Io and I did not know

688
00:30:36,230 --> 00:30:42,860
until today that Hubble actually was

689
00:30:39,409 --> 00:30:44,519
able to see a volcanic plume on Io from

690
00:30:42,859 --> 00:30:47,008
Earth I got

691
00:30:44,519 --> 00:30:49,649
say this compares very well to the New

692
00:30:47,009 --> 00:30:52,288
Horizons mission and one of my favorite

693
00:30:49,648 --> 00:30:56,248
images in all of astronomy this is the

694
00:30:52,288 --> 00:30:58,618
volcano Tabash star on Io captured by

695
00:30:56,249 --> 00:31:00,269
the New Horizons mission as it was

696
00:30:58,618 --> 00:31:05,128
getting a gravity assist flying by

697
00:31:00,269 --> 00:31:07,950
Jupiter so this is an in situ at Jupiter

698
00:31:05,128 --> 00:31:10,829
image whereas Hubble was able to

699
00:31:07,950 --> 00:31:13,588
actually see a plume as well being here

700
00:31:10,829 --> 00:31:15,838
at Earth and I've been working with

701
00:31:13,588 --> 00:31:18,058
Hubble for 13 years and that sort of

702
00:31:15,838 --> 00:31:22,048
surprised me that they were able to get

703
00:31:18,058 --> 00:31:25,348
that kind of that kind of observation in

704
00:31:22,048 --> 00:31:27,808
1997 we also looked at a favorite pair

705
00:31:25,348 --> 00:31:30,178
of galaxies for astronomers called the

706
00:31:27,808 --> 00:31:31,678
antennae galaxies and you might be able

707
00:31:30,179 --> 00:31:32,849
to understand why they were called the

708
00:31:31,679 --> 00:31:36,450
antennae because they have these big

709
00:31:32,848 --> 00:31:38,848
long plumes sticking out from these twin

710
00:31:36,450 --> 00:31:40,469
centers well looking at it with Hubble

711
00:31:38,848 --> 00:31:43,229
these are two galaxies that are

712
00:31:40,469 --> 00:31:45,419
colliding all right and with Hubble

713

00:31:43,229 --> 00:31:47,819
we're able to look into the detail into

714
00:31:45,419 --> 00:31:51,329
the core of this and you see all these

715
00:31:47,819 --> 00:31:54,028
blue star clusters revealing the intense

716
00:31:51,328 --> 00:31:56,878
star formation that happens when

717
00:31:54,028 --> 00:31:59,548
galaxies collide and in particular what

718
00:31:56,878 --> 00:32:00,808
Hubble was able to discover was if it's

719
00:31:59,548 --> 00:32:04,048
resolution it was able to see that these

720
00:32:00,808 --> 00:32:06,388
are not just star clusters but what the

721
00:32:04,048 --> 00:32:09,328
astronomer called super star clusters

722
00:32:06,388 --> 00:32:13,199
very very large clusters of stars that

723
00:32:09,328 --> 00:32:17,128
are formed when galaxies collide seen in

724
00:32:13,200 --> 00:32:20,298
the resolution with with the map Hubble

725
00:32:17,128 --> 00:32:23,308
looked at the antennae galaxies in

726
00:32:20,298 --> 00:32:26,519
1997-1998 flexed his muscle using the

727
00:32:23,308 --> 00:32:29,278

ultraviolet and stiff this is Saturn and

728

00:32:26,519 --> 00:32:32,249

you can see the aurora here on Saturn

729

00:32:29,278 --> 00:32:34,709

both in the south and up in the north

730

00:32:32,249 --> 00:32:35,999

now Saturn has Aurora like Earth does

731

00:32:34,709 --> 00:32:37,440

the Northern Lights

732

00:32:35,999 --> 00:32:39,239

and the southern lights or aurora

733

00:32:37,440 --> 00:32:43,798

borealis in the Aurora Australis

734

00:32:39,239 --> 00:32:45,659

however Saturn's Aurora is not visible

735

00:32:43,798 --> 00:32:48,269

with the invisible is not seen in

736

00:32:45,659 --> 00:32:50,909

visible light it is only seen in

737

00:32:48,269 --> 00:32:53,899

ultraviolet light so again you need a

738

00:32:50,909 --> 00:32:55,950

Space Telescope and the ultraviolet

739

00:32:53,898 --> 00:32:57,139

capabilities on Hubble were improved by

740

00:32:55,950 --> 00:32:59,808

a factor of 10

741

00:32:57,140 --> 00:33:03,020

with the addition of stiffers enabling us

742
00:32:59,808 --> 00:33:05,240
to see amazing detail in the Aurora on

743
00:33:03,019 --> 00:33:07,759
Saturn but also by the way the Aurora on

744
00:33:05,240 --> 00:33:11,720
Jupiter also visible in ultraviolet

745
00:33:07,759 --> 00:33:14,029
light in the infrared we looked toward

746
00:33:11,720 --> 00:33:14,750
Uranus now if you've seen any pictures

747
00:33:14,029 --> 00:33:18,349
of Uranus

748
00:33:14,750 --> 00:33:21,679
it's pretty boring it's a pretty blasé

749
00:33:18,349 --> 00:33:24,829
nothing of a planet that's viewing it

750
00:33:21,679 --> 00:33:26,840
using visible light in infrared light we

751
00:33:24,829 --> 00:33:29,449
were actually able to see storms on

752
00:33:26,839 --> 00:33:32,480
Uranus we're able to get the highlights

753
00:33:29,450 --> 00:33:36,080
of the Rings around Uranus and multiple

754
00:33:32,480 --> 00:33:38,509
of many several of its moons taking

755
00:33:36,079 --> 00:33:41,539
transforming Uranus from a rather bland

756
00:33:38,509 --> 00:33:43,190
greenish planet to something with with a

757
00:33:41,539 --> 00:33:48,319
lot more structure seeing a lot more

758
00:33:43,190 --> 00:33:51,289
detail in the atmosphere of Uranus 1998

759
00:33:48,319 --> 00:33:53,389
is also noticeable note notable because

760
00:33:51,289 --> 00:33:56,149
it was the start of the Hubble heritage

761
00:33:53,390 --> 00:33:58,970
project Hubble heritage project is a

762
00:33:56,150 --> 00:34:02,298
project to go through the Hubble archive

763
00:33:58,970 --> 00:34:04,730
and find the best Hubble images that

764
00:34:02,298 --> 00:34:07,009
haven't been released because of press

765
00:34:04,730 --> 00:34:09,260
not all the pretty pictures have a good

766
00:34:07,009 --> 00:34:10,190
press have have have great science that

767
00:34:09,260 --> 00:34:12,080
they're worthy of a press release

768
00:34:10,190 --> 00:34:14,030
there's a lot of really cool stuff in

769
00:34:12,079 --> 00:34:16,909
the Hubble archive and this project was

770

00:34:14,030 --> 00:34:19,909
started to go back and find those and in

771
00:34:16,909 --> 00:34:22,250
fact has blossomed into a major source

772
00:34:19,909 --> 00:34:24,648
of really cool Hubble images such that

773
00:34:22,250 --> 00:34:27,108
they often get some as time assigned to

774
00:34:24,648 --> 00:34:29,750
them in order to take really cool images

775
00:34:27,108 --> 00:34:32,179
for specifics for special special

776
00:34:29,750 --> 00:34:33,530
releases including our Hubble 25th

777
00:34:32,179 --> 00:34:34,539
anniversary image which I'll show you

778
00:34:33,530 --> 00:34:39,379
later

779
00:34:34,539 --> 00:34:41,809
now Edwin Hubble was notable know they

780
00:34:39,378 --> 00:34:44,089
had two major scientific compliments

781
00:34:41,809 --> 00:34:46,460
that people associated with him one is

782
00:34:44,090 --> 00:34:49,309
this observation of the Andromeda galaxy

783
00:34:46,460 --> 00:34:52,519
and really not the and he was looking

784
00:34:49,309 --> 00:34:54,049

these ends here indicate nobody okay he

785

00:34:52,519 --> 00:34:56,030

was looking for stars that would flash

786

00:34:54,050 --> 00:34:59,410

you're looking for nova in the andromeda

787

00:34:56,030 --> 00:35:02,119

galaxy but he found this one up here and

788

00:34:59,409 --> 00:35:06,739

actually found that it was a variable

789

00:35:02,119 --> 00:35:08,660

star and variable stars are special at

790

00:35:06,739 --> 00:35:09,949

least the Cepheid variable stars are

791

00:35:08,659 --> 00:35:12,409

special in

792

00:35:09,949 --> 00:35:13,879

the period of their variability the

793

00:35:12,409 --> 00:35:17,420

amount of time it takes them to brighten

794

00:35:13,880 --> 00:35:20,000

and dim and brighten again is related to

795

00:35:17,420 --> 00:35:22,490

their absolute brightness and if you

796

00:35:20,000 --> 00:35:24,230

know their absolute brightness and you

797

00:35:22,489 --> 00:35:27,829

can compare to the apparent brightness

798

00:35:24,230 --> 00:35:31,690

you can calculate distances and Hubble's

799

00:35:27,829 --> 00:35:34,759
second major second second major

800

00:35:31,690 --> 00:35:37,849
discovery was that the distances to

801

00:35:34,760 --> 00:35:38,780
various galaxies were proportional to

802

00:35:37,849 --> 00:35:40,699
their redshift

803

00:35:38,780 --> 00:35:43,730
now the redshift is a measure of their

804

00:35:40,699 --> 00:35:46,519
parent motion away from the Milky Way

805

00:35:43,730 --> 00:35:48,349
all right when we look out into space we

806

00:35:46,519 --> 00:35:50,900
see that all galaxies appear to be

807

00:35:48,349 --> 00:35:54,829
receding from us and interpret this as

808

00:35:50,900 --> 00:35:58,519
the expansion of the universe so these

809

00:35:54,829 --> 00:36:01,849
are Hubble's great observations but you

810

00:35:58,519 --> 00:36:05,000
know what Edwin Hubble didn't have a

811

00:36:01,849 --> 00:36:06,889
hubble space telescope so he actually

812

00:36:05,000 --> 00:36:09,679
got the slope of this line pretty wrong

813
00:36:06,889 --> 00:36:12,529
he actually used the wrong type of

814
00:36:09,679 --> 00:36:15,199
Cepheid variable and got his numbers

815
00:36:12,530 --> 00:36:17,330
kind of well they had a lot of error in

816
00:36:15,199 --> 00:36:19,909
them but for the time they were great

817
00:36:17,329 --> 00:36:22,599
but we had the Hubble and one of the key

818
00:36:19,909 --> 00:36:27,289
projects for the hubble space telescope

819
00:36:22,599 --> 00:36:29,809
was to nail down tighten up the

820
00:36:27,289 --> 00:36:31,639
expansion rate of the universe because

821
00:36:29,809 --> 00:36:33,920
at the time of Hubble's launched there

822
00:36:31,639 --> 00:36:35,750
was a camp that said no the universe is

823
00:36:33,920 --> 00:36:37,490
expanding at 50 kilometers per second

824
00:36:35,750 --> 00:36:38,989
per megaparsec you don't need to know

825
00:36:37,489 --> 00:36:40,879
what that means just you know that this

826
00:36:38,989 --> 00:36:42,529
was a 50 camp then there was another

827

00:36:40,880 --> 00:36:44,570
camp that said it was at a hundred

828
00:36:42,530 --> 00:36:46,340
kilometers per megaparsec okay

829
00:36:44,570 --> 00:36:49,490
kilometers per second per megaparsec and

830
00:36:46,340 --> 00:36:51,170
they were off by a factor of two all

831
00:36:49,489 --> 00:36:53,839
right and each of them had really good

832
00:36:51,170 --> 00:36:56,000
reasons for believing them so what we

833
00:36:53,840 --> 00:36:58,370
did with Hubble is we used those same

834
00:36:56,000 --> 00:37:00,949
Cepheid variables and we measured those

835
00:36:58,369 --> 00:37:02,630
Cepheid variables to all of as many

836
00:37:00,949 --> 00:37:04,909
local galaxies as we could using

837
00:37:02,630 --> 00:37:07,059
Hubble's resolution then of course

838
00:37:04,909 --> 00:37:09,829
measured the redshift for them and

839
00:37:07,059 --> 00:37:13,340
recalibrated a brand new Hubble diagram

840
00:37:09,829 --> 00:37:15,130
and this is a project that could not

841
00:37:13,340 --> 00:37:17,829

proceed during the first three years

842

00:37:15,130 --> 00:37:19,990

basically you needed the really

843

00:37:17,829 --> 00:37:22,480

the exquisite resolution that Hubble had

844

00:37:19,989 --> 00:37:24,159

after servicing mission 1 in order to

845

00:37:22,480 --> 00:37:26,440

proceed this so it took longer than we

846

00:37:24,159 --> 00:37:29,319

expected but after eight years of hard

847

00:37:26,440 --> 00:37:32,470

work and measuring the distances to 18

848

00:37:29,320 --> 00:37:35,039

different galaxies in the local area the

849

00:37:32,469 --> 00:37:37,659

HST key project on the Hubble constant

850

00:37:35,039 --> 00:37:39,849

finally released their result saying

851

00:37:37,659 --> 00:37:44,319

that the average in the local universe

852

00:37:39,849 --> 00:37:46,150

was a value of 70 plus or minus 10% and

853

00:37:44,320 --> 00:37:47,710

I know that doesn't sound sound sound

854

00:37:46,150 --> 00:37:50,079

like much but for an astronomers who are

855

00:37:47,710 --> 00:37:53,440

used to a factor of two to get it down

856
00:37:50,079 --> 00:37:55,769
to 10% was amazing this was the

857
00:37:53,440 --> 00:37:58,269
beginning of our precision cosmology

858
00:37:55,769 --> 00:38:00,759
when our cosmological models which when

859
00:37:58,269 --> 00:38:02,860
I was in graduate school were wildly

860
00:38:00,760 --> 00:38:04,270
variable and you could you could take a

861
00:38:02,860 --> 00:38:07,120
lot of different parameters and still

862
00:38:04,269 --> 00:38:09,929
fit the data finally we start getting

863
00:38:07,119 --> 00:38:12,339
precision we follow it up with the the

864
00:38:09,929 --> 00:38:14,949
Cosmic Microwave Background observations

865
00:38:12,340 --> 00:38:18,309
and such and over the course of Hubble's

866
00:38:14,949 --> 00:38:20,409
lifetime we have gone from from a lot of

867
00:38:18,309 --> 00:38:22,659
uncertainty in our models down to a very

868
00:38:20,409 --> 00:38:26,679
tightly fit model this is one of the key

869
00:38:22,659 --> 00:38:28,269
points in that transition another really

870
00:38:26,679 --> 00:38:30,219
cool thing that caught my eye I wasn't

871
00:38:28,269 --> 00:38:33,820
at Hubble at the time I was up in New

872
00:38:30,219 --> 00:38:38,349
York was this image right here HR 47 96

873
00:38:33,820 --> 00:38:40,539
a now what this is is a is an image

874
00:38:38,349 --> 00:38:43,569
where the light from the star has been

875
00:38:40,539 --> 00:38:45,190
blocked by an occulting spot okay it's

876
00:38:43,570 --> 00:38:46,750
like when you're looking at the Sun and

877
00:38:45,190 --> 00:38:48,639
you go oh I want to block that right

878
00:38:46,750 --> 00:38:51,309
well that's all we do in astronomy we

879
00:38:48,639 --> 00:38:54,299
block the light of the star in order to

880
00:38:51,309 --> 00:38:57,400
see the faint material around it and

881
00:38:54,300 --> 00:38:59,710
this is on the scale of the distance to

882
00:38:57,400 --> 00:39:04,000
that star the diameter of Neptune's

883
00:38:59,710 --> 00:39:06,010
orbit we had in the 1990s just begun

884

00:39:04,000 --> 00:39:09,909
discovered the Kuiper belt in our own

885
00:39:06,010 --> 00:39:13,180
solar system and when I we saw 47 96 a

886
00:39:09,909 --> 00:39:15,069
we pointed that and said damn that looks

887
00:39:13,179 --> 00:39:18,389
like we're seeing a Kuiper belt in

888
00:39:15,070 --> 00:39:21,940
another solar system around another star

889
00:39:18,389 --> 00:39:23,349
starting to see and in this one HD one

890
00:39:21,940 --> 00:39:27,269
four one five six nine

891
00:39:23,349 --> 00:39:30,159
you see rings but you also see a gap and

892
00:39:27,269 --> 00:39:32,199
gaps are really important because

893
00:39:30,159 --> 00:39:35,109
the only way a gap opens up is if

894
00:39:32,199 --> 00:39:37,539
there's a gravitational force pulling to

895
00:39:35,110 --> 00:39:39,309
create that gap it doesn't mean that

896
00:39:37,539 --> 00:39:41,079
there's a planet inside the gap there

897
00:39:39,309 --> 00:39:43,659
could be but there could also be a

898
00:39:41,079 --> 00:39:46,119

planet inside inside or outside that

899

00:39:43,659 --> 00:39:49,059

gravitational resonance is opening up

900

00:39:46,119 --> 00:39:51,009

that gap we're beginning to not only see

901

00:39:49,059 --> 00:39:52,630

planetary systems in formation but to

902

00:39:51,010 --> 00:39:54,780

start to see some of the details of

903

00:39:52,630 --> 00:39:59,019

planetary systems

904

00:39:54,780 --> 00:40:02,860

well 1999 ended on a sour note in

905

00:39:59,019 --> 00:40:05,199

November of 1999 we lost our fourth gyro

906

00:40:02,860 --> 00:40:07,630

when a Hubble has six gyroscopes on it

907

00:40:05,199 --> 00:40:09,730

and it needs three gyroscopes to point

908

00:40:07,630 --> 00:40:11,920

you've got three directions XY and Z and

909

00:40:09,730 --> 00:40:13,179

you need three gyroscopes to work with

910

00:40:11,920 --> 00:40:16,809

each other to point the telescope

911

00:40:13,179 --> 00:40:19,299

accurately well one of our fourth

912

00:40:16,809 --> 00:40:22,269

gyroscopes failed in November of 1999

913
00:40:19,300 --> 00:40:25,690
Hubble was paid to safe mode and Hubble

914
00:40:22,269 --> 00:40:28,869
could not do any more observations until

915
00:40:25,690 --> 00:40:31,900
the astronauts went up to repair it how

916
00:40:28,869 --> 00:40:34,809
long was that going to take not long

917
00:40:31,900 --> 00:40:38,380
NASA came to the rescue and in December

918
00:40:34,809 --> 00:40:40,719
1999 they put a Hubble servicing mission

919
00:40:38,380 --> 00:40:43,599
on to the manifest onto the shuttle

920
00:40:40,719 --> 00:40:47,619
manifest very quickly servicing mission

921
00:40:43,599 --> 00:40:49,269
3a now it's called 3a because we had a

922
00:40:47,619 --> 00:40:51,130
much larger servicing mission plan

923
00:40:49,269 --> 00:40:53,829
servicing full servicing mission three

924
00:40:51,130 --> 00:40:56,230
but because Hubble needed Hardware

925
00:40:53,829 --> 00:40:58,769
repairs they took the hardware repairs

926
00:40:56,230 --> 00:41:00,519
only and pushed it up in the schedule

927
00:40:58,769 --> 00:41:03,009
got up to Hubble

928
00:41:00,519 --> 00:41:06,219
almost immediately did the hardware

929
00:41:03,010 --> 00:41:08,110
repairs replace the gyroscopes you know

930
00:41:06,219 --> 00:41:11,379
topped off the fluids wash the

931
00:41:08,110 --> 00:41:13,960
windshield replace the magnet and the

932
00:41:11,380 --> 00:41:16,680
the recorders put on outer blanket

933
00:41:13,960 --> 00:41:19,119
layers insulation stuff like that okay

934
00:41:16,679 --> 00:41:22,029
didn't add any new capability to Hubble

935
00:41:19,119 --> 00:41:24,670
but repaired it and got it back into

936
00:41:22,030 --> 00:41:26,620
working order now of course when you

937
00:41:24,670 --> 00:41:28,780
have a successful servicing mission you

938
00:41:26,619 --> 00:41:31,329
have to announce it with with some

939
00:41:28,780 --> 00:41:33,970
beautiful images and in 2000 we

940
00:41:31,329 --> 00:41:36,460
announced it with this this was one of

941

00:41:33,969 --> 00:41:40,659
the images we use to announce it this is

942
00:41:36,460 --> 00:41:42,860
the galaxy cluster Abell 22-18 this is a

943
00:41:40,659 --> 00:41:46,369
galaxy cluster with thousands

944
00:41:42,860 --> 00:41:48,170
galaxies and the mass concentration in

945
00:41:46,369 --> 00:41:51,920
this globular cluster in this galaxy

946
00:41:48,170 --> 00:41:55,400
cluster is so great that it actually

947
00:41:51,920 --> 00:41:57,500
warps space now general relativity for

948
00:41:55,400 --> 00:41:58,700
those of you who come often there's a

949
00:41:57,500 --> 00:42:04,239
three word summary of general relativity

950
00:41:58,699 --> 00:42:07,819
anybody remember it mass warps space

951
00:42:04,239 --> 00:42:09,979
everybody say it with me mass warps

952
00:42:07,820 --> 00:42:12,230
space that's all you need to know about

953
00:42:09,980 --> 00:42:16,039
general relativity alright and there's

954
00:42:12,230 --> 00:42:19,579
so much mass in this galaxy cluster that

955
00:42:16,039 --> 00:42:22,009

the space has become warped and these

956

00:42:19,579 --> 00:42:24,829

are key streaky things that you see

957

00:42:22,010 --> 00:42:27,830

around this galaxy cluster are images of

958

00:42:24,829 --> 00:42:30,079

galaxies behind the cluster whose light

959

00:42:27,829 --> 00:42:32,989

has come through this warped space and

960

00:42:30,079 --> 00:42:34,909

becomes stretched out while passing

961

00:42:32,989 --> 00:42:37,489

through that warp space they're

962

00:42:34,909 --> 00:42:40,519

normal-looking galaxies but the images

963

00:42:37,489 --> 00:42:44,689

have become distorted by passing through

964

00:42:40,519 --> 00:42:49,400

distorted space how cool is that

965

00:42:44,690 --> 00:42:51,920

and you will note how thin and detailed

966

00:42:49,400 --> 00:42:54,320

you have to look in order to see these

967

00:42:51,920 --> 00:42:55,519

these gravitational lenses these

968

00:42:54,320 --> 00:42:59,800

gravitationally lensed

969

00:42:55,519 --> 00:43:02,449

arcs and Hubble's resolution has enabled

970
00:42:59,800 --> 00:43:05,720
greater studies of gravitational lensing

971
00:43:02,449 --> 00:43:08,389
than was ever possible before seeing

972
00:43:05,719 --> 00:43:11,480
that amazing detail these fine detailed

973
00:43:08,389 --> 00:43:14,210
structures possible with Hubble and

974
00:43:11,480 --> 00:43:17,119
gravitational lensing it has really

975
00:43:14,210 --> 00:43:21,110
greatly put forward on the field of that

976
00:43:17,119 --> 00:43:24,980
field 2001 we returned to the solar

977
00:43:21,110 --> 00:43:28,370
system and Mars makes periodic

978
00:43:24,980 --> 00:43:30,110
approaches by earth ok earth is orbiting

979
00:43:28,369 --> 00:43:32,449
around a little faster than Mars Mars

980
00:43:30,110 --> 00:43:35,150
takes a little bit longer every two two

981
00:43:32,449 --> 00:43:36,889
and a half years they come to what's

982
00:43:35,150 --> 00:43:40,340
called conjunction Earth and Mars are at

983
00:43:36,889 --> 00:43:43,759
their closest approach ok Hubble always

984
00:43:40,340 --> 00:43:46,430
takes pictures of Mars why because the

985
00:43:43,760 --> 00:43:48,590
public loves the solar system alright

986
00:43:46,429 --> 00:43:49,579
you know cosmology is great those

987
00:43:48,590 --> 00:43:52,130
gravitational lensing things are

988
00:43:49,579 --> 00:43:53,989
fantastic but you know what the public

989
00:43:52,130 --> 00:43:56,269
responds to a solar system press release

990
00:43:53,989 --> 00:43:58,668
more than anything else

991
00:43:56,268 --> 00:44:00,258
also it's a really good time to study

992
00:43:58,668 --> 00:44:02,568
Mars and we've got the best resolution

993
00:44:00,259 --> 00:44:04,668
that you can say you can have from Earth

994
00:44:02,568 --> 00:44:05,989
now of course the resolution is nothing

995
00:44:04,668 --> 00:44:08,239
compared to the spacecraft that are

996
00:44:05,989 --> 00:44:10,759
there at Mars we can't compete with that

997
00:44:08,239 --> 00:44:13,099
but you know we can do we can do some

998

00:44:10,759 --> 00:44:16,668
things one of the things we can do which

999
00:44:13,099 --> 00:44:19,669
we can monitor it long term see in June

1000
00:44:16,668 --> 00:44:22,818
of 2001 here's the picture of Mars and

1001
00:44:19,668 --> 00:44:25,358
you see that down that's the helis basin

1002
00:44:22,818 --> 00:44:28,489
down there and there was a dust storm

1003
00:44:25,358 --> 00:44:30,528
brewing in the Hellas Basin okay a giant

1004
00:44:28,489 --> 00:44:33,168
impact crater on Mars got a dust storm

1005
00:44:30,528 --> 00:44:34,429
brewing and so we watched it and we

1006
00:44:33,168 --> 00:44:39,219
looked in September

1007
00:44:34,429 --> 00:44:42,079
oh no is the flaw in the mirror back no

1008
00:44:39,219 --> 00:44:45,639
the dust storm that was a localized

1009
00:44:42,079 --> 00:44:46,809
disturbance in June has gone global in

1010
00:44:45,639 --> 00:44:50,509
September

1011
00:44:46,809 --> 00:44:53,089
Mars's atmosphere is 1/100 the density

1012
00:44:50,509 --> 00:44:55,519

of Earth's atmosphere and localized

1013

00:44:53,088 --> 00:44:58,699

disturbances can propagate to become

1014

00:44:55,518 --> 00:44:59,088

global phenomena that's what happens

1015

00:44:58,699 --> 00:45:02,298

here

1016

00:44:59,088 --> 00:45:06,068

Hubble gets to monitor the planets over

1017

00:45:02,298 --> 00:45:09,288

the course of decades when you send a

1018

00:45:06,068 --> 00:45:12,108

spacecraft to a planet it's there for a

1019

00:45:09,289 --> 00:45:13,729

few years you know a Cassini is done

1020

00:45:12,108 --> 00:45:15,619

absolutely amazing being there as long

1021

00:45:13,728 --> 00:45:17,658

as it has been but Hubble is around

1022

00:45:15,619 --> 00:45:18,949

there for decades and sometimes I like

1023

00:45:17,659 --> 00:45:21,798

to refer to Hubble as the interplanetary

1024

00:45:18,949 --> 00:45:24,079

weather channel because it can monitor

1025

00:45:21,798 --> 00:45:29,239

what's going on in these planets from

1026

00:45:24,079 --> 00:45:34,969

here at earth over long-term 2001 also

1027
00:45:29,239 --> 00:45:37,749
saw an amazing amazing discovery this is

1028
00:45:34,969 --> 00:45:43,009
the Hubble Deep Field that was done in

1029
00:45:37,748 --> 00:45:44,928
1995 and in that ours this galaxies here

1030
00:45:43,009 --> 00:45:48,889
this the small suite of galaxies here

1031
00:45:44,929 --> 00:45:53,599
and in this galaxy here we observed a

1032
00:45:48,889 --> 00:45:58,189
supernova this galaxy is however 10

1033
00:45:53,599 --> 00:46:01,609
billion light years away making this the

1034
00:45:58,188 --> 00:46:03,378
most distant supernovae ever observed

1035
00:46:01,608 --> 00:46:05,478
now what you're seeing the lower

1036
00:46:03,378 --> 00:46:08,208
right-hand panel is basically two images

1037
00:46:05,478 --> 00:46:09,439
of this of these galaxies subtracted to

1038
00:46:08,208 --> 00:46:11,750
show you the light remain

1039
00:46:09,440 --> 00:46:16,190
that extra light that came from that

1040
00:46:11,750 --> 00:46:21,318
supernova now what's really cool about

1041
00:46:16,190 --> 00:46:24,889
this is that this supernova being so far

1042
00:46:21,318 --> 00:46:27,349
away being able to give us the distance

1043
00:46:24,889 --> 00:46:29,420
to that galaxy and compare it to its

1044
00:46:27,349 --> 00:46:33,550
redshift like we did with the Hubble

1045
00:46:29,420 --> 00:46:37,068
diagram was helped able to nail down a

1046
00:46:33,550 --> 00:46:40,130
cosmological model as you may be aware

1047
00:46:37,068 --> 00:46:43,099
in the late 1990s we had evidence that

1048
00:46:40,130 --> 00:46:44,720
the universe was accelerating the

1049
00:46:43,099 --> 00:46:46,338
expansion of the universe instead of

1050
00:46:44,719 --> 00:46:50,419
slowing down like we'd always thought it

1051
00:46:46,338 --> 00:46:53,929
would appears to be going faster but we

1052
00:46:50,420 --> 00:46:55,760
couldn't really tell unless we look way

1053
00:46:53,929 --> 00:46:58,848
way out in the universe our confidence

1054
00:46:55,760 --> 00:47:00,950
locally was very strong but unless we

1055

00:46:58,849 --> 00:47:02,539
looked way way out in the universe to

1056
00:47:00,949 --> 00:47:07,399
see back when the universe was slowing

1057
00:47:02,539 --> 00:47:11,210
down could we truly tell this galaxy

1058
00:47:07,400 --> 00:47:13,700
this supernova at a redshift of 1.7 the

1059
00:47:11,210 --> 00:47:17,809
most distant supernova ever observed was

1060
00:47:13,699 --> 00:47:19,939
a crucial point in getting in accepting

1061
00:47:17,809 --> 00:47:23,358
the accelerating universe and the

1062
00:47:19,940 --> 00:47:27,889
discovery of dark energy the kind of

1063
00:47:23,358 --> 00:47:30,139
thing only observable with Hubble 2002

1064
00:47:27,889 --> 00:47:34,549
we got the second half of servicing

1065
00:47:30,139 --> 00:47:37,460
mission 3 servicing mission 3b and again

1066
00:47:34,550 --> 00:47:40,640
the wonderful astronauts who went up and

1067
00:47:37,460 --> 00:47:44,088
serviced it now 2,000 smidgen 3b was

1068
00:47:40,639 --> 00:47:47,029
especially cool because we had for the

1069
00:47:44,088 --> 00:47:49,190

first time a major change of our primary

1070

00:47:47,030 --> 00:47:51,730

observing instrument we had been using

1071

00:47:49,190 --> 00:47:54,019

wide field planetary camera 2 since 1993

1072

00:47:51,730 --> 00:47:56,809

which was installed and servicing

1073

00:47:54,019 --> 00:47:58,130

mission 1 and in this servicing mission

1074

00:47:56,809 --> 00:48:01,639

we installed the advanced camera for

1075

00:47:58,130 --> 00:48:06,950

surveys going from a 3 megapixel camera

1076

00:48:01,639 --> 00:48:09,348

to a 16 megapixel camera going from one

1077

00:48:06,949 --> 00:48:11,889

tenth of an arcsecond resolution to one

1078

00:48:09,349 --> 00:48:15,109

twentieth of mark second resolution so

1079

00:48:11,889 --> 00:48:19,239

slightly larger field of view higher

1080

00:48:15,108 --> 00:48:21,920

resolution more pixels really exciting

1081

00:48:19,239 --> 00:48:22,909

we also during this mission I'll have to

1082

00:48:21,920 --> 00:48:27,650

say there

1083

00:48:22,909 --> 00:48:29,239

a power unit repair and I have to say

1084
00:48:27,650 --> 00:48:31,460
that one of the most dramatic lines I've

1085
00:48:29,239 --> 00:48:33,078
heard a NASA you know the the NASA guys

1086
00:48:31,460 --> 00:48:34,760
who are who are narrating these things

1087
00:48:33,079 --> 00:48:38,539
and they're very calm and very

1088
00:48:34,760 --> 00:48:40,069
professional he said something like you

1089
00:48:38,539 --> 00:48:41,690
know that when they disconnected the

1090
00:48:40,068 --> 00:48:44,179
power unit in order to do the repair

1091
00:48:41,690 --> 00:48:49,720
he said for the first time Hubble is

1092
00:48:44,179 --> 00:48:49,719
without a heartbeat it was like whoa

1093
00:48:49,900 --> 00:48:53,780
fortunately Hubble did recover from

1094
00:48:52,190 --> 00:48:57,200
open-heart surgery uh-huh

1095
00:48:53,780 --> 00:48:59,089
to go on and do amazing things with our

1096
00:48:57,199 --> 00:49:01,429
early release observations we included

1097
00:48:59,088 --> 00:49:03,828
this image of the mice galaxies which

1098
00:49:01,429 --> 00:49:05,960
looks a bit like the antennae but it's

1099
00:49:03,829 --> 00:49:07,460
now at Hubble resolution that antenna

1100
00:49:05,960 --> 00:49:09,858
image I showed you was from the ground

1101
00:49:07,460 --> 00:49:12,409
here you get to see all the detail as

1102
00:49:09,858 --> 00:49:15,980
well as those big long tidal tails and

1103
00:49:12,409 --> 00:49:18,250
the mice were part of our press release

1104
00:49:15,980 --> 00:49:20,480
to say Hubble is back and working

1105
00:49:18,250 --> 00:49:23,349
perhaps the most successful press

1106
00:49:20,480 --> 00:49:29,059
release we've ever done because we got

1107
00:49:23,349 --> 00:49:32,028
one two three four Hubble images on the

1108
00:49:29,059 --> 00:49:37,298
front page of the New York Times in full

1109
00:49:32,028 --> 00:49:40,278
color above the fold a grand slam of

1110
00:49:37,298 --> 00:49:43,278
public outreach if ever there was one

1111
00:49:40,278 --> 00:49:44,119
I don't know how we could possibly do

1112

00:49:43,278 --> 00:49:47,389
any better than that

1113
00:49:44,119 --> 00:49:49,269
so but we have tried for the past 13

1114
00:49:47,389 --> 00:49:51,440
years all right

1115
00:49:49,269 --> 00:49:54,469
2003 that advanced camera for surveys

1116
00:49:51,440 --> 00:49:57,139
puts it 16 megapixels to use and we

1117
00:49:54,469 --> 00:50:00,528
start doing mosaics this is a mosaic of

1118
00:49:57,139 --> 00:50:03,288
72 million pixels of the sombrero galaxy

1119
00:50:00,528 --> 00:50:06,019
and it's a gorgeous galaxy with it's

1120
00:50:03,289 --> 00:50:08,809
amazing dust disk and the big halo of

1121
00:50:06,019 --> 00:50:11,119
stars but also you'll find that the

1122
00:50:08,809 --> 00:50:14,150
background galaxies all the details in

1123
00:50:11,119 --> 00:50:15,980
the background ACS is that much more

1124
00:50:14,150 --> 00:50:17,778
sensitive that it's not just the

1125
00:50:15,980 --> 00:50:19,039
foreground objects but we find ourselves

1126
00:50:17,778 --> 00:50:21,798

starting looking through the background

1127

00:50:19,039 --> 00:50:24,700

objects we're seeing amazing detail in

1128

00:50:21,798 --> 00:50:28,788

the background of all our images as well

1129

00:50:24,699 --> 00:50:31,519

too we also took a very deep look at a

1130

00:50:28,789 --> 00:50:34,069

nothing part near the Andromeda galaxy

1131

00:50:31,519 --> 00:50:35,750

so this is the region that we studied

1132

00:50:34,068 --> 00:50:38,329

well away from the center of the

1133

00:50:35,750 --> 00:50:40,369

a galaxy in the halo of the andromeda

1134

00:50:38,329 --> 00:50:44,299

galaxy we did what we call the stellar

1135

00:50:40,369 --> 00:50:47,210

deep field and this is an image in one

1136

00:50:44,300 --> 00:50:50,289

at which almost all the stars you see

1137

00:50:47,210 --> 00:50:53,269

are not in our galaxy

1138

00:50:50,289 --> 00:50:57,199

almost all the stars you see are in the

1139

00:50:53,269 --> 00:50:59,539

Andromeda galaxy this is an amazingly

1140

00:50:57,199 --> 00:51:03,109

deep image to study the stellar

1141
00:50:59,539 --> 00:51:05,480
populations within the Andromeda galaxy

1142
00:51:03,110 --> 00:51:07,579
for example okay by the way these also

1143
00:51:05,480 --> 00:51:08,809
are background galaxies we can't get rid

1144
00:51:07,579 --> 00:51:11,179
of them okay they're gonna be in the

1145
00:51:08,809 --> 00:51:14,110
background at all times but see this guy

1146
00:51:11,179 --> 00:51:17,719
right here that is a globular cluster

1147
00:51:14,110 --> 00:51:20,450
not in our galaxy but in the end dromeda

1148
00:51:17,719 --> 00:51:23,359
galaxy and for comparison I give you a

1149
00:51:20,449 --> 00:51:25,699
globular cluster in our own galaxy also

1150
00:51:23,360 --> 00:51:29,090
taken with Hubble Messier 80 in the

1151
00:51:25,699 --> 00:51:31,539
Milky Way and I guess what is it g1 or

1152
00:51:29,090 --> 00:51:33,650
something like that in Andromeda

1153
00:51:31,539 --> 00:51:36,320
absolutely amazing that we can get this

1154
00:51:33,650 --> 00:51:41,200
detail from a galaxy two-and-a-half

1155
00:51:36,320 --> 00:51:45,440
million light-years away unfortunately

1156
00:51:41,199 --> 00:51:47,210
this is a shot of the astronauts at the

1157
00:51:45,440 --> 00:51:49,300
landing of the space shuttle Columbia

1158
00:51:47,210 --> 00:51:51,289
after servicing mission three and

1159
00:51:49,300 --> 00:51:53,269
unfortunately this was the last

1160
00:51:51,289 --> 00:51:55,969
successful mission of the space shuttle

1161
00:51:53,269 --> 00:51:58,309
Columbia on its next mission it

1162
00:51:55,969 --> 00:52:01,789
disintegrated as it was coming in over

1163
00:51:58,309 --> 00:52:04,759
Texas and this gentleman right here Sean

1164
00:52:01,789 --> 00:52:10,070
O'Keefe was the then NASA Administrator

1165
00:52:04,760 --> 00:52:12,200
and in January of 2004 he decided that

1166
00:52:10,070 --> 00:52:15,350
it was too dangerous to go back to

1167
00:52:12,199 --> 00:52:17,750
Hubble that there was no safe haven for

1168
00:52:15,349 --> 00:52:18,949
the astronauts if they were going to the

1169

00:52:17,750 --> 00:52:20,480
space station

1170
00:52:18,949 --> 00:52:22,250
well the astronauts could hang out on

1171
00:52:20,480 --> 00:52:25,639
the space station if there was a problem

1172
00:52:22,250 --> 00:52:28,219
with the shuttle until a rescue mission

1173
00:52:25,639 --> 00:52:28,969
could be sent up but Hubble there was no

1174
00:52:28,219 --> 00:52:32,059
safe haven

1175
00:52:28,969 --> 00:52:34,339
so in January 2004 he announced the

1176
00:52:32,059 --> 00:52:36,739
cancellation of our last servicing

1177
00:52:34,340 --> 00:52:41,890
mission servicing mission for would be

1178
00:52:36,739 --> 00:52:43,809
no more I cannot describe the

1179
00:52:41,889 --> 00:52:47,949
I don't want to say depression but they

1180
00:52:43,809 --> 00:52:50,349
just the general around this building at

1181
00:52:47,949 --> 00:52:51,939
the time all right we'd been through so

1182
00:52:50,349 --> 00:52:53,769
much in getting and Hubble has tries

1183
00:52:51,940 --> 00:52:58,030

triumph but to not have that last

1184

00:52:53,769 --> 00:52:59,469

servicing mission well that was a that

1185

00:52:58,030 --> 00:53:02,410

was quite a blow we've already started

1186

00:52:59,469 --> 00:53:04,089

building the instruments for it okay but

1187

00:53:02,409 --> 00:53:06,549

that's not that doesn't mean that the

1188

00:53:04,090 --> 00:53:09,990

science stops so this is an image

1189

00:53:06,550 --> 00:53:14,440

released in 1994 looking at supernova

1190

00:53:09,989 --> 00:53:15,969

1987a now 87a is the closest supernova

1191

00:53:14,440 --> 00:53:17,710

since the invention of the telescope

1192

00:53:15,969 --> 00:53:19,750

it's actually in the Large Magellanic

1193

00:53:17,710 --> 00:53:21,849

Cloud a satellite galaxy of the Milky

1194

00:53:19,750 --> 00:53:23,679

Way we've been very unlucky for the past

1195

00:53:21,849 --> 00:53:28,500

four hundred years we haven't had a good

1196

00:53:23,679 --> 00:53:31,839

supernova in our own galaxy but 87a

1197

00:53:28,500 --> 00:53:34,119

explode we observe the explosion in 1987

1198
00:53:31,840 --> 00:53:36,039
and this was the Hubble image in 1994

1199
00:53:34,119 --> 00:53:38,529
and you can see here is the star that

1200
00:53:36,039 --> 00:53:42,269
exploded here you can see there's a ring

1201
00:53:38,530 --> 00:53:45,760
here and these two amazing rings here

1202
00:53:42,269 --> 00:53:49,090
indicating that before the star exploded

1203
00:53:45,760 --> 00:53:50,050
there was some outbursts of material to

1204
00:53:49,090 --> 00:53:53,410
create these rings

1205
00:53:50,050 --> 00:53:55,690
whether it was jets illuminating this

1206
00:53:53,409 --> 00:53:57,789
you know rotating jets that would

1207
00:53:55,690 --> 00:54:00,220
illuminate the of these rings you have

1208
00:53:57,789 --> 00:54:01,960
this ring of material here well we've

1209
00:54:00,219 --> 00:54:04,299
been following it ever since

1210
00:54:01,960 --> 00:54:07,389
okay the closest supernova you betcha

1211
00:54:04,300 --> 00:54:09,460
Hubble's gonna follow it and in 2004 we

1212
00:54:07,389 --> 00:54:12,339
released this amazing series images of

1213
00:54:09,460 --> 00:54:14,170
that central ring so here is that ring

1214
00:54:12,340 --> 00:54:15,430
this bright spot here is just a star

1215
00:54:14,170 --> 00:54:18,430
that happens to be along the line of

1216
00:54:15,429 --> 00:54:22,750
sight so you can ignore that but as we

1217
00:54:18,429 --> 00:54:26,139
go through 95 96 to 98 you start to see

1218
00:54:22,750 --> 00:54:26,650
other bright spots lighting up along the

1219
00:54:26,139 --> 00:54:29,019
ring

1220
00:54:26,650 --> 00:54:32,860
you'll also notice this central region

1221
00:54:29,019 --> 00:54:35,530
becoming blurrier and bigger until in

1222
00:54:32,860 --> 00:54:38,710
2003 you can see the entire ring is

1223
00:54:35,530 --> 00:54:41,260
basically lit up and this is the

1224
00:54:38,710 --> 00:54:44,110
supernova remnant what's happening here

1225
00:54:41,260 --> 00:54:46,870
is the star explodes and a shockwave

1226

00:54:44,110 --> 00:54:47,410
is sent out at tens of millions of miles

1227
00:54:46,869 --> 00:54:50,559
an hour

1228
00:54:47,409 --> 00:54:52,559
across interstellar space what you're

1229
00:54:50,559 --> 00:54:56,000
seeing here is that shockwave

1230
00:54:52,559 --> 00:54:58,639
encountering that inner ring and

1231
00:54:56,000 --> 00:55:01,909
heating up that inner ring we're seeing

1232
00:54:58,639 --> 00:55:03,769
in real-time the shockwave smashing into

1233
00:55:01,909 --> 00:55:07,909
this ring creating all these bright

1234
00:55:03,769 --> 00:55:11,780
regions plus we are seeing the gas of

1235
00:55:07,909 --> 00:55:14,119
the supernova remnant expand out in real

1236
00:55:11,780 --> 00:55:16,460
time we've been following this ever

1237
00:55:14,119 --> 00:55:19,519
since it's absolutely amazing not too

1238
00:55:16,460 --> 00:55:22,220
many things in astronomy happen in real

1239
00:55:19,519 --> 00:55:23,929
time and Hubble has been there to be

1240
00:55:22,219 --> 00:55:29,389

able to monitor the expansion of

1241
00:55:23,929 --> 00:55:30,829
supernova 87a now also in 1996 we did

1242
00:55:29,389 --> 00:55:35,779
the Hubble Deep Field I'd mentioned it

1243
00:55:30,829 --> 00:55:38,329
previously this was quite a risky

1244
00:55:35,780 --> 00:55:41,180
observation basically the director at

1245
00:55:38,329 --> 00:55:44,119
the time put all his discretionary time

1246
00:55:41,179 --> 00:55:45,889
into one observation and it's an

1247
00:55:44,119 --> 00:55:49,819
observation that a lot of astronomers

1248
00:55:45,889 --> 00:55:52,730
said would totally fail because distant

1249
00:55:49,820 --> 00:55:54,800
galaxies if you believe some models were

1250
00:55:52,730 --> 00:55:58,070
predicted to be too small for even

1251
00:55:54,800 --> 00:56:00,410
Hubble to see that as you go further out

1252
00:55:58,070 --> 00:56:03,380
the galaxies smaller and smaller you're

1253
00:56:00,409 --> 00:56:05,239
not going to be able to see anything but

1254
00:56:03,380 --> 00:56:07,550
he put all his eggs in one basket and

1255
00:56:05,239 --> 00:56:10,339
produced this amazing image the Hubble

1256
00:56:07,550 --> 00:56:13,220
Deep Field showing that you really could

1257
00:56:10,340 --> 00:56:15,590
do deep universe observations with how

1258
00:56:13,219 --> 00:56:18,169
well that Hubble's resolution was good

1259
00:56:15,590 --> 00:56:20,059
enough well we got the advanced camera

1260
00:56:18,170 --> 00:56:22,250
for surveys the direct new director said

1261
00:56:20,059 --> 00:56:24,309
I got to repeat this with our new

1262
00:56:22,250 --> 00:56:28,250
instrument with twice the resolution and

1263
00:56:24,309 --> 00:56:30,409
many times the pixels and so in 2004 we

1264
00:56:28,250 --> 00:56:35,710
also came out with the Hubble Ultra Deep

1265
00:56:30,409 --> 00:56:38,449
Field okay and this is probably the most

1266
00:56:35,710 --> 00:56:41,240
scientifically productive image Hubble

1267
00:56:38,449 --> 00:56:44,659
has ever created all right it has

1268
00:56:41,239 --> 00:56:46,699
approximately 10,000 galaxies all the

1269
00:56:44,659 --> 00:56:49,549
way stretched across space and time

1270
00:56:46,699 --> 00:56:52,039
looking way out into the universe from

1271
00:56:49,550 --> 00:56:53,539
our big nearby galaxies and when I say

1272
00:56:52,039 --> 00:56:55,400
nearby I know that that galaxy is about

1273
00:56:53,539 --> 00:56:57,529
two billion light-years away so that's

1274
00:56:55,400 --> 00:56:59,869
nearby in this image just a couple

1275
00:56:57,530 --> 00:57:01,670
billion light-years away is nearby all

1276
00:56:59,869 --> 00:57:03,079
the way down to I don't know if I can

1277
00:57:01,670 --> 00:57:05,599
pick out one of the red dots there's a

1278
00:57:03,079 --> 00:57:07,159
bunch of little red tiny red dots you

1279
00:57:05,599 --> 00:57:08,589
probably can't see it at this resolution

1280
00:57:07,159 --> 00:57:12,279
tiny time

1281
00:57:08,590 --> 00:57:15,340
red dot stretching out 10 billion

1282
00:57:12,280 --> 00:57:17,530
light-years across the universe a core

1283

00:57:15,340 --> 00:57:21,550
sample through the universe looking at

1284
00:57:17,530 --> 00:57:25,570
galaxies out in space but also back in

1285
00:57:21,550 --> 00:57:28,960
time because this galaxy being 2 billion

1286
00:57:25,570 --> 00:57:32,110
light years away the light has taken 2

1287
00:57:28,960 --> 00:57:35,530
billion years to cross the intervening

1288
00:57:32,110 --> 00:57:41,440
space so we're seeing this galaxy as it

1289
00:57:35,530 --> 00:57:45,550
was 2 billion years ago this image looks

1290
00:57:41,440 --> 00:57:48,550
out into space back into time and shows

1291
00:57:45,550 --> 00:57:49,980
us the history of galaxy development

1292
00:57:48,550 --> 00:57:52,900
across the universe

1293
00:57:49,980 --> 00:57:54,579
you know a history teacher can't look

1294
00:57:52,900 --> 00:57:57,610
out and see the battles of get Battle of

1295
00:57:54,579 --> 00:58:00,400
Gettysburg but we as astronomers can

1296
00:57:57,610 --> 00:58:03,640
look out and see what galaxies were like

1297
00:58:00,400 --> 00:58:06,039

billions of years ago to give us an

1298

00:58:03,639 --> 00:58:09,750

understanding of how galaxies developed

1299

00:58:06,039 --> 00:58:09,750

to be with it the way they are today

1300

00:58:09,900 --> 00:58:17,260

unfortunately in early 2005 the advanced

1301

00:58:14,230 --> 00:58:20,019

camera for surveys its warranty

1302

00:58:17,260 --> 00:58:22,180

obviously expired and it had an

1303

00:58:20,019 --> 00:58:24,670

electrical fault okay all of our

1304

00:58:22,179 --> 00:58:26,889

instruments on Hubble have redundant

1305

00:58:24,670 --> 00:58:29,230

electronics the one side of the

1306

00:58:26,889 --> 00:58:31,239

electronics had failed previously the

1307

00:58:29,230 --> 00:58:32,980

second side of the electronics failed our

1308

00:58:31,239 --> 00:58:35,259

main instrument the instrument that took

1309

00:58:32,980 --> 00:58:36,159

that Hubble Ultra Deep Field image was

1310

00:58:35,260 --> 00:58:39,180

now offline

1311

00:58:36,159 --> 00:58:42,429

here it is 2005 and what are we gonna do

1312
00:58:39,179 --> 00:58:44,829
we're gonna go back to the white oak I'm

1313
00:58:42,429 --> 00:58:48,039
sorry this isn't this is an ACS this is

1314
00:58:44,829 --> 00:58:49,900
this just failed in 2005 ACS will fail a

1315
00:58:48,039 --> 00:58:53,349
little a little later sorry about that I

1316
00:58:49,900 --> 00:58:55,690
blown it the surprise is gone okay um

1317
00:58:53,349 --> 00:58:58,389
the Space Telescope imaging spectrograph

1318
00:58:55,690 --> 00:58:59,950
failed first I'm sorry I should know

1319
00:58:58,389 --> 00:59:02,019
because the the picture of the ACS

1320
00:58:59,949 --> 00:59:04,179
actually says ACS on it all right this

1321
00:59:02,019 --> 00:59:06,250
is not them trying to repair it this is

1322
00:59:04,179 --> 00:59:09,250
actually as they were building this dis

1323
00:59:06,250 --> 00:59:10,510
instrument okay not to get anybody think

1324
00:59:09,250 --> 00:59:14,219
that we actually could go up and do this

1325
00:59:10,510 --> 00:59:17,950
kind of repair so we're without still

1326
00:59:14,219 --> 00:59:20,019
2005 our 15th anniversary we released

1327
00:59:17,949 --> 00:59:20,559
this amazing image of the Whirlpool

1328
00:59:20,019 --> 00:59:21,789
Galaxy

1329
00:59:20,559 --> 00:59:26,199
also known as

1330
00:59:21,789 --> 00:59:28,659
see a 50 196 million pixels of visual

1331
00:59:26,199 --> 00:59:30,339
goodness here what I love about this

1332
00:59:28,659 --> 00:59:33,129
image is that you can see the

1333
00:59:30,340 --> 00:59:35,320
progression of star formation within a

1334
00:59:33,130 --> 00:59:38,710
galaxy you've got the dark dust lanes

1335
00:59:35,320 --> 00:59:40,870
that that identify the spiral arms that

1336
00:59:38,710 --> 00:59:43,030
trace the spiral arms outside of them

1337
00:59:40,869 --> 00:59:45,250
you've got all these pink regions these

1338
00:59:43,030 --> 00:59:47,130
are the star forming regions we're still

1339
00:59:45,250 --> 00:59:50,559
where that dense gas and the dust

1340

00:59:47,130 --> 00:59:52,360
collapses and creates new stars and then

1341
00:59:50,559 --> 00:59:54,369
outside of those pink regions you see

1342
00:59:52,360 --> 00:59:57,880
these wonderful blue star clusters the

1343
00:59:54,369 --> 01:00:00,309
newborn stars going from the dense gas

1344
00:59:57,880 --> 01:00:02,079
that collapses to the stars that form to

1345
01:00:00,309 --> 01:00:06,610
the star clusters that are revealed when

1346
01:00:02,079 --> 01:00:09,099
that star formation is done also in 2005

1347
01:00:06,610 --> 01:00:13,930
we got this amazing picture of the Crab

1348
01:00:09,099 --> 01:00:16,000
Nebula this is a supernova not 10 or 20

1349
01:00:13,929 --> 01:00:18,250
years after it had exploded but a

1350
01:00:16,000 --> 01:00:20,920
thousand years after it exploded this

1351
01:00:18,250 --> 01:00:24,880
supernova was observed by chinese

1352
01:00:20,920 --> 01:00:27,490
astronomers in 1054 I believe about a

1353
01:00:24,880 --> 01:00:29,380
thousand years ago and all that material

1354
01:00:27,489 --> 01:00:31,719

streaming across space you saw that

1355

01:00:29,380 --> 01:00:34,360

little nebulous starting to form in the

1356

01:00:31,719 --> 01:00:37,059

center of a supernova 87a this is what

1357

01:00:34,360 --> 01:00:39,460

it looks like a thousand years later for

1358

01:00:37,059 --> 01:00:42,039

the Crab Nebula if you want to take a

1359

01:00:39,460 --> 01:00:44,670

look at one that's 30,000 years old we

1360

01:00:42,039 --> 01:00:48,099

also got a picture of Cassiopeia A in

1361

01:00:44,670 --> 01:00:50,650

2006 an older supernova remnant that has

1362

01:00:48,099 --> 01:00:53,259

expanded across space for 30,000 years

1363

01:00:50,650 --> 01:00:56,289

leaving a beautiful bubble this bubble

1364

01:00:53,260 --> 01:00:59,410

like shell the star that exploded long

1365

01:00:56,289 --> 01:01:02,769

gone and seeing the shell of material

1366

01:00:59,409 --> 01:01:05,139

and this exemplifies the cosmic

1367

01:01:02,769 --> 01:01:07,449

recycling in our galaxy that the

1368

01:01:05,139 --> 01:01:09,639

elements form inside stars you fuse

1369
01:01:07,449 --> 01:01:12,909
hydrogen to helium helium to carbon

1370
01:01:09,639 --> 01:01:14,589
nitrogen oxygen and so on up the ladder

1371
01:01:12,909 --> 01:01:16,149
and then with these giant supernova

1372
01:01:14,590 --> 01:01:22,030
explosions those elements are blown

1373
01:01:16,150 --> 01:01:25,090
across space and recycled into into the

1374
01:01:22,030 --> 01:01:27,790
interstellar medium and in some pockets

1375
01:01:25,090 --> 01:01:30,370
of those interstellar medium stars will

1376
01:01:27,789 --> 01:01:33,420
form and around some of those stars

1377
01:01:30,369 --> 01:01:35,679
planets will form and the heavy elements

1378
01:01:33,420 --> 01:01:42,159
which can only form

1379
01:01:35,679 --> 01:01:47,319
inside these stars form to create all

1380
01:01:42,159 --> 01:01:50,069
the carbon in your the oxygen in your in

1381
01:01:47,320 --> 01:01:52,930
your lungs the calcium in your teeth

1382
01:01:50,070 --> 01:01:55,660
because of the carbon in our bones all

1383
01:01:52,929 --> 01:01:58,569
of those elements were forged in the

1384
01:01:55,659 --> 01:02:02,289
interiors of stars and blown across

1385
01:01:58,570 --> 01:02:04,930
space by these supernova remnants so

1386
01:02:02,289 --> 01:02:10,059
there's a great cosmic connection to

1387
01:02:04,929 --> 01:02:12,339
images like this 2006 also produced one

1388
01:02:10,059 --> 01:02:14,469
of my favorite images simply because we

1389
01:02:12,340 --> 01:02:16,630
got to work with it on the IMAX film of

1390
01:02:14,469 --> 01:02:19,649
the Orion Nebula now I showed you the

1391
01:02:16,630 --> 01:02:23,079
1995 version of Orion that was a

1392
01:02:19,650 --> 01:02:26,889
relatively small region in here this one

1393
01:02:23,079 --> 01:02:28,630
is much larger actually it was so large

1394
01:02:26,889 --> 01:02:31,509
that we couldn't with the computers of

1395
01:02:28,630 --> 01:02:35,559
the time process the entire image you'll

1396
01:02:31,510 --> 01:02:38,920
find on our website is about a 320

1397

01:02:35,559 --> 01:02:40,210
million pixel image the full one had we

1398
01:02:38,920 --> 01:02:41,950
been able to process it at full

1399
01:02:40,210 --> 01:02:44,170
resolution and release it would have

1400
01:02:41,949 --> 01:02:46,269
been about a billion pixels which for

1401
01:02:44,170 --> 01:02:49,000
the computers at the time was not I'm

1402
01:02:46,269 --> 01:02:51,579
not feasible but again even more detail

1403
01:02:49,000 --> 01:02:54,309
of the amazing star formation going on

1404
01:02:51,579 --> 01:03:00,219
inside this nearest of the large star

1405
01:02:54,309 --> 01:03:03,400
foreign regions to us good news 2006

1406
01:03:00,219 --> 01:03:06,009
also saw a we had a new NASA

1407
01:03:03,400 --> 01:03:09,840
Administrator Michael Griffin he came on

1408
01:03:06,010 --> 01:03:11,910
if a couple years before this and he

1409
01:03:09,840 --> 01:03:14,350
commissioned a study to look at

1410
01:03:11,909 --> 01:03:16,779
servicing mission a possibility of a

1411
01:03:14,349 --> 01:03:19,480

servicing mission for and in the middle

1412

01:03:16,780 --> 01:03:23,530

of the year he added a servicing mission

1413

01:03:19,480 --> 01:03:25,990

for back onto the manifest but in order

1414

01:03:23,530 --> 01:03:27,610

to protect the astronauts it was decreed

1415

01:03:25,989 --> 01:03:29,229

that he could not do his Hubble

1416

01:03:27,610 --> 01:03:33,190

servicing mission unless there was a

1417

01:03:29,230 --> 01:03:36,400

second shuttle on the launch pad ready

1418

01:03:33,190 --> 01:03:38,980

to go in case a rescue mission was

1419

01:03:36,400 --> 01:03:40,840

needed so that was our solution if

1420

01:03:38,980 --> 01:03:43,150

you're gonna go to Hubble you need two

1421

01:03:40,840 --> 01:03:45,490

shuttles on the launch pad at the same

1422

01:03:43,150 --> 01:03:47,920

time of course that it happened before

1423

01:03:45,489 --> 01:03:49,500

it Hubble's launch so we're gonna do it

1424

01:03:47,920 --> 01:03:52,298

again

1425

01:03:49,500 --> 01:03:54,358

as we might say the mood around this

1426
01:03:52,298 --> 01:03:58,000
building really lightened after that

1427
01:03:54,358 --> 01:04:00,578
much jubilation after that however this

1428
01:03:58,000 --> 01:04:03,599
is when ACS now you can see it is ACS

1429
01:04:00,579 --> 01:04:07,539
because there it is um ACS failed

1430
01:04:03,599 --> 01:04:09,039
alright so again without the Space

1431
01:04:07,539 --> 01:04:11,049
Telescope imaging spectrograph or

1432
01:04:09,039 --> 01:04:12,789
without the advanced camera surveys two

1433
01:04:11,048 --> 01:04:15,099
of our really important instruments are

1434
01:04:12,789 --> 01:04:16,839
no longer working we really really want

1435
01:04:15,099 --> 01:04:19,500
that servicing mission to come as soon

1436
01:04:16,838 --> 01:04:22,509
as possible but it was scheduled for

1437
01:04:19,500 --> 01:04:25,838
2008 so we got lots of science to go

1438
01:04:22,510 --> 01:04:30,250
through 2007 this is an artist's

1439
01:04:25,838 --> 01:04:34,119
illustration of a of a planet around a

1440
01:04:30,250 --> 01:04:36,699
star and in a jupiter-sized planet in a

1441
01:04:34,119 --> 01:04:40,720
mercury sized orbit we call them hot

1442
01:04:36,699 --> 01:04:43,118
Jupiters but this one actually passes in

1443
01:04:40,719 --> 01:04:47,709
front of it of the star from our point

1444
01:04:43,119 --> 01:04:49,599
of view which makes it really cool well

1445
01:04:47,710 --> 01:04:52,539
actually it's really hot but really cool

1446
01:04:49,599 --> 01:04:55,450
to study because you can see as that

1447
01:04:52,539 --> 01:04:57,250
planet passes in front of its star some

1448
01:04:55,449 --> 01:05:00,189
of the light of the star will go through

1449
01:04:57,250 --> 01:05:03,278
the atmosphere of this star and this

1450
01:05:00,190 --> 01:05:06,068
star is so cool this planet is so close

1451
01:05:03,278 --> 01:05:08,920
to its star that it's atmospheres

1452
01:05:06,068 --> 01:05:11,018
actually heated up and extended so if

1453
01:05:08,920 --> 01:05:13,568
you take a picture or a spectrograph

1454

01:05:11,018 --> 01:05:15,848
when the planet is in front of the star

1455
01:05:13,568 --> 01:05:18,239
and take another when the planet is not

1456
01:05:15,849 --> 01:05:22,869
in front of the star subtract the two

1457
01:05:18,239 --> 01:05:25,929
what do you get you get to measure the

1458
01:05:22,869 --> 01:05:28,599
atmosphere of a planet around another

1459
01:05:25,929 --> 01:05:31,048
star now you can't actually see this

1460
01:05:28,599 --> 01:05:33,490
planet but you can measure its

1461
01:05:31,048 --> 01:05:35,139
atmosphere and this atmosphere is

1462
01:05:33,489 --> 01:05:37,808
extended and we're able to measure

1463
01:05:35,139 --> 01:05:40,000
hydrogen and silicon and nitrogen a

1464
01:05:37,809 --> 01:05:43,630
couple other elements in the atmosphere

1465
01:05:40,000 --> 01:05:47,588
of another planet and I have to say this

1466
01:05:43,630 --> 01:05:50,349
is one of the Hubble discoveries that we

1467
01:05:47,588 --> 01:05:52,838
hadn't even dreamed of when Hubble was

1468
01:05:50,349 --> 01:05:56,019

launched one of the great things about

1469

01:05:52,838 --> 01:05:58,449

science is that if you design a general

1470

01:05:56,018 --> 01:06:00,929

purpose instrument you could actually do

1471

01:05:58,449 --> 01:06:02,559

science you didn't even think possible

1472

01:06:00,929 --> 01:06:04,629

when

1473

01:06:02,559 --> 01:06:07,239

when you initially conceived of the idea

1474

01:06:04,630 --> 01:06:12,340

and this is one of the one of the major

1475

01:06:07,239 --> 01:06:15,719

ones also in 2007 we got well this was

1476

01:06:12,340 --> 01:06:19,300

our this was until last Monday the

1477

01:06:15,719 --> 01:06:22,569

largest mosaic Hubble has ever done this

1478

01:06:19,300 --> 01:06:24,820

is of the Carina Nebula another star

1479

01:06:22,570 --> 01:06:26,680

forming region that ATAC our image that

1480

01:06:24,820 --> 01:06:29,470

I showed you is this small thing right

1481

01:06:26,679 --> 01:06:31,599

here down inside there you can see it's

1482

01:06:29,469 --> 01:06:33,369

just part of a much larger star forming

1483
01:06:31,599 --> 01:06:36,159
region you can see there's an amazing

1484
01:06:33,369 --> 01:06:37,809
bubble a cavity drawn by these bright

1485
01:06:36,159 --> 01:06:40,509
stars and they're hot winds and

1486
01:06:37,809 --> 01:06:42,549
everything and we've got this the

1487
01:06:40,510 --> 01:06:44,890
pillars here and pillars down here and

1488
01:06:42,550 --> 01:06:49,840
all sorts of cool stuff going on in here

1489
01:06:44,889 --> 01:06:52,629
this 350 300 400 million pixel image

1490
01:06:49,840 --> 01:06:57,150
shows off the incredible detail Hubble

1491
01:06:52,630 --> 01:07:00,010
can see in these star forming regions

1492
01:06:57,150 --> 01:07:02,289
2008 well let's get to Jupiter because

1493
01:07:00,010 --> 01:07:03,670
we talked about Jupiter's storms we

1494
01:07:02,289 --> 01:07:05,409
talked about Saturn's storms and how

1495
01:07:03,670 --> 01:07:07,960
Jupiter is used to having storm well we

1496
01:07:05,409 --> 01:07:09,129
are used to one major storm always being

1497
01:07:07,960 --> 01:07:12,070
there on Jupiter

1498
01:07:09,130 --> 01:07:13,750
and that is the great red spot we have

1499
01:07:12,070 --> 01:07:15,910
seen it ever since we started looking at

1500
01:07:13,750 --> 01:07:19,659
we have continuous observations back to

1501
01:07:15,909 --> 01:07:22,960
the 1800s we may even have seen it back

1502
01:07:19,659 --> 01:07:26,049
in 1670 when Giovanni Cassini he's got a

1503
01:07:22,960 --> 01:07:27,940
wonderful drawing in a 1670 scientific

1504
01:07:26,050 --> 01:07:30,789
journal and I swear it looks like the

1505
01:07:27,940 --> 01:07:32,099
Great Red Spot so it's always been there

1506
01:07:30,789 --> 01:07:35,759
all right

1507
01:07:32,099 --> 01:07:38,650
in 2003 several of these white ovals

1508
01:07:35,760 --> 01:07:42,280
merged to form what we called Red Spot

1509
01:07:38,650 --> 01:07:45,369
jr. the first time we'd ever seen the

1510
01:07:42,280 --> 01:07:49,900
formation of a Red Spot and in early

1511

01:07:45,369 --> 01:07:52,449
2008 another red spot appeared this was

1512
01:07:49,900 --> 01:07:56,110
the Great Red Spot red jr. so we call

1513
01:07:52,449 --> 01:07:58,299
that baby red spot now red jr. is on a

1514
01:07:56,110 --> 01:08:00,460
different latitude and has passed by the

1515
01:07:58,300 --> 01:08:02,400
great red spots several times and

1516
01:08:00,460 --> 01:08:05,769
appears to be a long live storm

1517
01:08:02,400 --> 01:08:08,710
however red the baby red spot is on the

1518
01:08:05,769 --> 01:08:11,530
same latitude as Jupiter and so we

1519
01:08:08,710 --> 01:08:13,960
watched over the summer of 2008 as it

1520
01:08:11,530 --> 01:08:15,019
got caught in the vortices and was

1521
01:08:13,960 --> 01:08:16,430
dissipated

1522
01:08:15,019 --> 01:08:20,270
for the first time we saw the

1523
01:08:16,430 --> 01:08:21,980
destruction of a red spot and we also

1524
01:08:20,270 --> 01:08:24,680
learned how vicious the great red spot

1525
01:08:21,979 --> 01:08:31,548

is it's such a vicious storm it'll even

1526

01:08:24,680 --> 01:08:35,480

eat its own young 2008 also saw this

1527

01:08:31,548 --> 01:08:37,189

wonderful image this is a forum a lot or

1528

01:08:35,479 --> 01:08:39,199

actually it's everything but the star

1529

01:08:37,189 --> 01:08:41,000

forum a lot again the light of fo Milan

1530

01:08:39,199 --> 01:08:42,528

has been blocked and it's got a dust

1531

01:08:41,000 --> 01:08:43,838

ring around it looks similar to some of

1532

01:08:42,529 --> 01:08:46,580

the show images I've shown you before

1533

01:08:43,838 --> 01:08:49,579

but the special thing about this dust

1534

01:08:46,579 --> 01:08:52,729

ring is that it's off-center FOMA hot is

1535

01:08:49,579 --> 01:08:54,588

not at the center which indicates that

1536

01:08:52,729 --> 01:08:57,649

there's some gravitational influence

1537

01:08:54,588 --> 01:08:59,960

pulling it off center so it was searched

1538

01:08:57,649 --> 01:09:05,358

to see if we could find a planet in it

1539

01:08:59,960 --> 01:09:09,649

and in 2008 we saw the first image ever

1540
01:09:05,359 --> 01:09:14,120
of a planet around another star right

1541
01:09:09,649 --> 01:09:15,858
there a beautiful red dot but it's an

1542
01:09:14,119 --> 01:09:18,920
amazing red dot when you think of it

1543
01:09:15,859 --> 01:09:21,289
because this is not a planet I'm telling

1544
01:09:18,920 --> 01:09:23,869
you is there because if it's gravity or

1545
01:09:21,289 --> 01:09:27,019
because I detect it blocking some light

1546
01:09:23,869 --> 01:09:30,979
it's not an indirect detection this is

1547
01:09:27,020 --> 01:09:32,779
the first direct detection on a planet

1548
01:09:30,979 --> 01:09:34,789
around another star now this is the one

1549
01:09:32,779 --> 01:09:37,970
in visible light using visible light in

1550
01:09:34,789 --> 01:09:40,369
the exact same issue of the exact same

1551
01:09:37,970 --> 01:09:43,569
scientific journal another group

1552
01:09:40,369 --> 01:09:48,170
released images in infrared light so

1553
01:09:43,569 --> 01:09:50,779
starting in 2008 we finally have direct

1554
01:09:48,170 --> 01:09:54,829
detection seeing planets around other

1555
01:09:50,779 --> 01:09:57,080
stars and you think about how we've come

1556
01:09:54,829 --> 01:09:59,119
far we come over the first 18 years of

1557
01:09:57,079 --> 01:10:00,350
Hubble going from not even knowing there

1558
01:09:59,119 --> 01:10:03,470
were planets around other stars

1559
01:10:00,350 --> 01:10:05,600
to finally seeing them you can see what

1560
01:10:03,470 --> 01:10:10,640
a spectrum of science this mission has

1561
01:10:05,600 --> 01:10:12,890
covered 2008 was that finally we get

1562
01:10:10,640 --> 01:10:15,320
around to servicing mission 4 and a

1563
01:10:12,890 --> 01:10:17,270
quote from a higher high ranking person

1564
01:10:15,319 --> 01:10:20,210
at NASA says this final mission will be

1565
01:10:17,270 --> 01:10:22,910
without doubt the most complicated and

1566
01:10:20,210 --> 01:10:27,079
challenging that nASA has ever mounted

1567
01:10:22,909 --> 01:10:28,909
so here we are in September of 2008 we

1568

01:10:27,079 --> 01:10:31,399
have the Space Shuttle on the line

1569
01:10:28,909 --> 01:10:32,750
we have the second space shuttle on the

1570
01:10:31,399 --> 01:10:35,000
launch pad there's a beautiful rainbow

1571
01:10:32,750 --> 01:10:38,210
up here that I had to crop off to get

1572
01:10:35,000 --> 01:10:43,189
the image in amazing shot all right

1573
01:10:38,210 --> 01:10:44,569
we're ready to go and then a science

1574
01:10:43,189 --> 01:10:48,349
instrument control and data handling

1575
01:10:44,569 --> 01:10:50,210
unit failed now this was just the a side

1576
01:10:48,350 --> 01:10:52,579
of the electronics of the si si and EH

1577
01:10:50,210 --> 01:10:55,130
and there was a B side so we immediately

1578
01:10:52,579 --> 01:10:57,409
switched to the B side but science

1579
01:10:55,130 --> 01:10:59,750
instrument control this is the hardware

1580
01:10:57,409 --> 01:11:02,510
that controls every science instrument

1581
01:10:59,750 --> 01:11:03,979
on Hubble data handling unit every bit

1582
01:11:02,510 --> 01:11:07,220

of data goes through this piece of

1583

01:11:03,979 --> 01:11:09,589

hardware so when it failed three weeks

1584

01:11:07,220 --> 01:11:12,530

before launch and even though it was a

1585

01:11:09,590 --> 01:11:14,270

repairable fail we didn't want to have

1586

01:11:12,529 --> 01:11:17,719

any single points of failure

1587

01:11:14,270 --> 01:11:20,570

so NASA delayed the mission while a

1588

01:11:17,720 --> 01:11:23,659

ground spare that Goddard Space Flight

1589

01:11:20,569 --> 01:11:25,579

Center was made ready for space so that

1590

01:11:23,659 --> 01:11:28,880

mission that we've been waiting for was

1591

01:11:25,579 --> 01:11:31,640

delayed yet another six months until May

1592

01:11:28,880 --> 01:11:35,180

of 2009 when we finally got the launch

1593

01:11:31,640 --> 01:11:37,610

of servicing mission 4 now servicing

1594

01:11:35,180 --> 01:11:39,800

mission 4 tackled an enormous number of

1595

01:11:37,609 --> 01:11:41,989

tasks because it was the final mission

1596

01:11:39,800 --> 01:11:44,029

to Hubble and we knew it we were not

1597
01:11:41,989 --> 01:11:46,849
going to get another mission to Hubble

1598
01:11:44,029 --> 01:11:50,420
so we changed out the batteries we put

1599
01:11:46,850 --> 01:11:52,670
in new gyros we put a pulled out wide

1600
01:11:50,420 --> 01:11:56,180
field planetary camera 2 we put in Wide

1601
01:11:52,670 --> 01:11:59,300
Field Camera 3 we repaired ACS we

1602
01:11:56,180 --> 01:12:02,210
repaired this we put in new insulation

1603
01:11:59,300 --> 01:12:04,970
we did everything possible to leave

1604
01:12:02,210 --> 01:12:08,270
Hubble and as good a shape as paw as we

1605
01:12:04,970 --> 01:12:09,440
could and unbelievably the astronauts

1606
01:12:08,270 --> 01:12:11,900
accomplished it all

1607
01:12:09,439 --> 01:12:13,250
they went well past their space time the

1608
01:12:11,899 --> 01:12:15,710
time they're supposed to do for

1609
01:12:13,250 --> 01:12:18,920
spacewalks they accomplished everything

1610
01:12:15,710 --> 01:12:21,529
on the list all right and this is a

1611
01:12:18,920 --> 01:12:24,319
bittersweet shot because this is Hubble

1612
01:12:21,529 --> 01:12:27,649
repaired but this is also the last time

1613
01:12:24,319 --> 01:12:29,719
human eyes got to see Hubble because as

1614
01:12:27,649 --> 01:12:31,639
the astronauts were leaving this is one

1615
01:12:29,720 --> 01:12:35,480
of the last shots they got saying

1616
01:12:31,640 --> 01:12:38,060
goodbye to Hubble of course the science

1617
01:12:35,479 --> 01:12:40,250
comes out amazing the early-release

1618
01:12:38,060 --> 01:12:41,130
observations included the butterfly

1619
01:12:40,250 --> 01:12:43,439
nebula

1620
01:12:41,130 --> 01:12:44,850
actually it's called the bug nebula but

1621
01:12:43,439 --> 01:12:46,888
our press release said it looked like a

1622
01:12:44,850 --> 01:12:48,719
butterfly and the press ran with it

1623
01:12:46,889 --> 01:12:53,940
so now most people call it the butterfly

1624
01:12:48,719 --> 01:12:56,789
nebula this is a dying star a planetary

1625

01:12:53,939 --> 01:12:57,960
nebula as they call it not because it

1626
01:12:56,789 --> 01:12:59,369
has anything to do with planets but

1627
01:12:57,960 --> 01:13:02,158
that's just what they were called

1628
01:12:59,369 --> 01:13:05,069
and the material streaming away from the

1629
01:13:02,158 --> 01:13:07,619
star is constrained by a disc around

1630
01:13:05,069 --> 01:13:10,079
here so it goes off in these hourglass

1631
01:13:07,619 --> 01:13:12,840
shapes here creating an amazing and

1632
01:13:10,079 --> 01:13:14,579
beautiful wheel nebula we also released

1633
01:13:12,840 --> 01:13:17,100
this image of the core of the globular

1634
01:13:14,579 --> 01:13:19,439
cluster omega centauri i talked to you

1635
01:13:17,100 --> 01:13:22,800
about the detail Hubble can see inside

1636
01:13:19,439 --> 01:13:25,138
globular clusters this was not intended

1637
01:13:22,800 --> 01:13:27,719
to be a press release image it's a test

1638
01:13:25,139 --> 01:13:31,199
image because the blue is ultraviolet

1639
01:13:27,719 --> 01:13:33,510

the red is infrared it was a test image

1640

01:13:31,198 --> 01:13:36,059

to show off the broad wavelength

1641

01:13:33,510 --> 01:13:37,980

coverage of Wide Field Camera 3 the

1642

01:13:36,060 --> 01:13:40,650

largest wavelength coverage of any

1643

01:13:37,979 --> 01:13:43,049

instrument ever on Hubble to show up but

1644

01:13:40,649 --> 01:13:45,000

it was such an amazing image that it

1645

01:13:43,050 --> 01:13:47,789

ended up making it wait its way into the

1646

01:13:45,000 --> 01:13:51,448

press package both of those images were

1647

01:13:47,789 --> 01:13:55,800

featured in the IMAX film Hubble 3d and

1648

01:13:51,448 --> 01:13:58,589

my personal note on this was that when

1649

01:13:55,800 --> 01:14:02,520

the servicing mission was delayed from

1650

01:13:58,590 --> 01:14:05,670

October to May the film's release date

1651

01:14:02,520 --> 01:14:08,130

was not and those of us working on the

1652

01:14:05,670 --> 01:14:09,960

computer graphics for this film had to

1653

01:14:08,130 --> 01:14:11,850

wait until after the servicing mission

1654
01:14:09,960 --> 01:14:13,889
because the IMAX director couldn't pay

1655
01:14:11,850 --> 01:14:15,960
any attention to doing the beautiful

1656
01:14:13,889 --> 01:14:17,190
shots we were doing until after the

1657
01:14:15,960 --> 01:14:18,989
service mission was done and she'd

1658
01:14:17,189 --> 01:14:21,629
gotten the footage from the servicing

1659
01:14:18,988 --> 01:14:23,339
mission to put in the film so that delay

1660
01:14:21,630 --> 01:14:25,739
the servicing mission actually meant we

1661
01:14:23,340 --> 01:14:28,139
had six-month less time to work on the

1662
01:14:25,738 --> 01:14:29,669
computer graphics for the film but we

1663
01:14:28,139 --> 01:14:30,600
still accomplished it was really

1664
01:14:29,670 --> 01:14:32,670
wonderful

1665
01:14:30,600 --> 01:14:35,130
but that delay hit me in a way that I

1666
01:14:32,670 --> 01:14:37,770
had never even expected when it would

1667
01:14:35,130 --> 01:14:41,010
happen but that film has grossed over

1668
01:14:37,770 --> 01:14:43,860
fifty million dollars worldwide which is

1669
01:14:41,010 --> 01:14:47,400
tremendous for a documentary it's on

1670
01:14:43,859 --> 01:14:51,750
track to become one of the top 5 IMAX

1671
01:14:47,399 --> 01:14:54,089
documentary fans of all time 2010 for

1672
01:14:51,750 --> 01:14:54,988
Hubble's 20th anniversary released this

1673
01:14:54,090 --> 01:14:58,139
image which we

1674
01:14:54,988 --> 01:15:00,388
named mystic mountain and it is again

1675
01:14:58,139 --> 01:15:02,400
pillars like the pillars in the Eagle

1676
01:15:00,389 --> 01:15:04,590
Nebula but here you can see we've got

1677
01:15:02,399 --> 01:15:07,109
these jets of materials streaming off up

1678
01:15:04,590 --> 01:15:08,819
here this are what I call the birth

1679
01:15:07,109 --> 01:15:11,158
announcements of a newborn star when

1680
01:15:08,819 --> 01:15:13,889
stars are born they often have these

1681
01:15:11,158 --> 01:15:15,538
twin pillars of jets streaming out and

1682

01:15:13,889 --> 01:15:19,078
you can see up not only here but also

1683
01:15:15,538 --> 01:15:22,460
here again gorgeous ionization fronts

1684
01:15:19,078 --> 01:15:27,238
but this time with jets to show them off

1685
01:15:22,460 --> 01:15:29,550
2011 the galaxies ARP 273 something that

1686
01:15:27,238 --> 01:15:31,468
was nicknamed the rose because these two

1687
01:15:29,550 --> 01:15:33,869
galaxies have been interacting but only

1688
01:15:31,469 --> 01:15:35,368
gently and you can see that this galaxy

1689
01:15:33,868 --> 01:15:36,808
has become stretched out and got a

1690
01:15:35,368 --> 01:15:39,569
little bit of tidal tails up and down

1691
01:15:36,809 --> 01:15:41,579
whereas the spiral arms of this galaxy

1692
01:15:39,569 --> 01:15:42,988
have been stretched out and if you sort

1693
01:15:41,578 --> 01:15:47,488
of squinted it you can see this is the

1694
01:15:42,988 --> 01:15:49,888
stem with the rose up at the top 2011

1695
01:15:47,488 --> 01:15:52,138
also saw the awarding of the Nobel Prize

1696
01:15:49,889 --> 01:15:54,389

in Physics to Adam Riess here at the

1697

01:15:52,139 --> 01:15:56,699

Space Telescope Science Institute and to

1698

01:15:54,389 --> 01:15:59,010

be fair it was awarded for the work he

1699

01:15:56,698 --> 01:16:01,259

did on the accelerating universe before

1700

01:15:59,010 --> 01:16:04,340

he was here but as I mentioned before

1701

01:16:01,260 --> 01:16:07,050

because Hubble played a pivotal role in

1702

01:16:04,340 --> 01:16:09,179

verifying and giving the scientific

1703

01:16:07,050 --> 01:16:11,190

community trust that the accelerating

1704

01:16:09,179 --> 01:16:13,199

universe was correct we like to

1705

01:16:11,189 --> 01:16:14,908

celebrate it - he's also here if you

1706

01:16:13,198 --> 01:16:17,848

want to see a replica of the Nobel Prize

1707

01:16:14,908 --> 01:16:21,839

it's a medal it's out in the lobby and

1708

01:16:17,849 --> 01:16:23,699

you can see it as you go out 2012

1709

01:16:21,840 --> 01:16:25,769

remember that Pluto Charon picture I

1710

01:16:23,698 --> 01:16:28,319

showed you the very beginning from 1990

1711
01:16:25,769 --> 01:16:29,998
well we would be on looking around Pluto

1712
01:16:28,319 --> 01:16:32,849
for the new Horizons mission which will

1713
01:16:29,998 --> 01:16:36,538
get to Pluto in July of this year we

1714
01:16:32,849 --> 01:16:40,460
found not one not two not three but four

1715
01:16:36,538 --> 01:16:44,158
other moons around Pluto and Charon

1716
01:16:40,460 --> 01:16:46,260
basically taking from 2 to 6 the number

1717
01:16:44,158 --> 01:16:49,738
of targets the new Horizons mission has

1718
01:16:46,260 --> 01:16:51,780
to look at so the detail and Hubble with

1719
01:16:49,738 --> 01:16:53,908
its new instruments able to see really

1720
01:16:51,779 --> 01:16:56,908
fine and faint things out at the edge of

1721
01:16:53,908 --> 01:16:58,768
our solar system we can also see really

1722
01:16:56,908 --> 01:17:00,779
fine and faint things out of the edge of

1723
01:16:58,769 --> 01:17:02,400
the universe but for that we're gonna

1724
01:17:00,779 --> 01:17:04,228
use a little bit of help because I talk

1725
01:17:02,399 --> 01:17:07,109
to you about gravitational lensing and

1726
01:17:04,229 --> 01:17:07,920
how there is a lens in space but we can

1727
01:17:07,109 --> 01:17:10,738
use that

1728
01:17:07,920 --> 01:17:13,050
to magnify really distant galaxies and

1729
01:17:10,738 --> 01:17:17,159
see galaxies that Hubble could never

1730
01:17:13,050 --> 01:17:20,159
otherwise see these images jd1 jt2 283

1731
01:17:17,159 --> 01:17:22,500
are all of the same galaxy that has

1732
01:17:20,159 --> 01:17:25,529
whose light has been not just distorted

1733
01:17:22,500 --> 01:17:27,600
but also magnified so Hubble can see it

1734
01:17:25,529 --> 01:17:31,349
this is the one of the most distant

1735
01:17:27,600 --> 01:17:36,170
galaxy candidates ever discovered at or

1736
01:17:31,350 --> 01:17:38,280
at almost 13 billion light-years away I

1737
01:17:36,170 --> 01:17:43,230
never remember the numbers on those it's

1738
01:17:38,279 --> 01:17:44,789
between 12 and 13 okay ah 2013 we start

1739

01:17:43,229 --> 01:17:47,399
revisiting some images we had taken

1740
01:17:44,789 --> 01:17:49,859
before this is the famed Horsehead

1741
01:17:47,399 --> 01:17:53,639
Nebula which in using visible light has

1742
01:17:49,859 --> 01:17:55,710
a great dark column and there's not much

1743
01:17:53,640 --> 01:17:58,560
to see if there's not much detail in it

1744
01:17:55,710 --> 01:18:00,960
but with the new infrared capability of

1745
01:17:58,560 --> 01:18:05,699
Wide Field Camera 3 we take this same

1746
01:18:00,960 --> 01:18:08,219
image on a larger field and you get a

1747
01:18:05,698 --> 01:18:11,609
glowing gaseous landscape in the

1748
01:18:08,219 --> 01:18:13,260
infrared all sorts of detail shows up in

1749
01:18:11,609 --> 01:18:15,389
when you look in the infrared and see

1750
01:18:13,260 --> 01:18:17,489
the cooler gas and the structures that

1751
01:18:15,390 --> 01:18:20,489
you can see in in the Horsehead Nebula

1752
01:18:17,488 --> 01:18:21,359
we also revisited that Hubble ultra-deep

1753
01:18:20,488 --> 01:18:23,189

field

1754

01:18:21,359 --> 01:18:26,789
we'd been revisiting it in the infrared

1755

01:18:23,189 --> 01:18:28,619
in 2009 and so we were able to get

1756

01:18:26,789 --> 01:18:31,948
further and deeper in the infrared and

1757

01:18:28,619 --> 01:18:33,840
in 2014 we said let's extend that to the

1758

01:18:31,948 --> 01:18:36,269
ultraviolet let's take advantage that we

1759

01:18:33,840 --> 01:18:38,000
have ultraviolet visible and infrared

1760

01:18:36,270 --> 01:18:41,570
and together we Pruce the

1761

01:18:38,000 --> 01:18:44,719
multi-wavelength Ultra Deep Field in

1762

01:18:41,569 --> 01:18:48,750
2014 the deepest image of the universe

1763

01:18:44,719 --> 01:18:51,689
covering a broad spectrum of colors so

1764

01:18:48,750 --> 01:18:55,020
based on all that what are we gonna do

1765

01:18:51,689 --> 01:18:57,029
for the 25th anniversary well for the

1766

01:18:55,020 --> 01:19:00,480
25th anniversary we decided we would

1767

01:18:57,029 --> 01:19:04,079
revisit a classic we would go back to

1768
01:19:00,479 --> 01:19:06,119
that pillars of creation from 1995 and

1769
01:19:04,079 --> 01:19:07,679
you can see how it has that stair-step

1770
01:19:06,119 --> 01:19:10,829
shape due to a wide field planetary

1771
01:19:07,679 --> 01:19:13,969
camera - we would go in with wide field

1772
01:19:10,829 --> 01:19:17,519
camera 3 look at it and I present to you

1773
01:19:13,969 --> 01:19:21,500
the 25th anniversary image the new wisi

1774
01:19:17,520 --> 01:19:21,500
3 image of the pillars of creation

1775
01:19:22,439 --> 01:19:28,750
you can see it covers a much larger

1776
01:19:25,539 --> 01:19:31,149
field of view at greater detail twice

1777
01:19:28,750 --> 01:19:33,550
the resolution there's approximately 60

1778
01:19:31,149 --> 01:19:35,259
million pixels of visual goodness for

1779
01:19:33,550 --> 01:19:37,630
you to explore you can see that those

1780
01:19:35,260 --> 01:19:38,980
pillars fade out here but yet new

1781
01:19:37,630 --> 01:19:40,659
pillars are underneath I sort of think

1782
01:19:38,979 --> 01:19:43,299
of this as a it looks like at the tree

1783
01:19:40,659 --> 01:19:46,329
stump underneath it you can also see how

1784
01:19:43,300 --> 01:19:49,119
the gasps fades away as that streaming

1785
01:19:46,329 --> 01:19:51,039
of it pulls the gas off I had a friend

1786
01:19:49,119 --> 01:19:52,630
at the SS who said oh I know what that

1787
01:19:51,039 --> 01:19:55,000
looks like that looks like the Dementors

1788
01:19:52,630 --> 01:19:59,140
from Harry Potter alright so this should

1789
01:19:55,000 --> 01:20:01,239
be the DeMint or pillar oh but let's

1790
01:19:59,140 --> 01:20:04,119
take it one step further because we have

1791
01:20:01,239 --> 01:20:06,969
with c3 it has broad wavelength coverage

1792
01:20:04,119 --> 01:20:12,909
we can look in the infrared and in the

1793
01:20:06,970 --> 01:20:15,070
infrared we see that I talked to you

1794
01:20:12,909 --> 01:20:16,750
about how these pillars have these dense

1795
01:20:15,069 --> 01:20:18,639
regions at the top but aren't

1796

01:20:16,750 --> 01:20:21,489
necessarily dense all the way down here

1797
01:20:18,640 --> 01:20:23,410
you can truly see that there are not

1798
01:20:21,489 --> 01:20:25,329
dense all the way down if I go back to

1799
01:20:23,409 --> 01:20:28,090
the visible light you can see that the

1800
01:20:25,329 --> 01:20:30,489
gas of the nebula obscures all the

1801
01:20:28,090 --> 01:20:32,680
background if we go to the infrared all

1802
01:20:30,489 --> 01:20:34,389
of those background stars start to

1803
01:20:32,680 --> 01:20:36,760
appear you can even see some background

1804
01:20:34,390 --> 01:20:39,250
galaxies in through here take a look at

1805
01:20:36,760 --> 01:20:41,650
these four bright stars they're very

1806
01:20:39,250 --> 01:20:46,119
bright in the infrared but where are

1807
01:20:41,649 --> 01:20:48,519
they in visible light okay looking in

1808
01:20:46,119 --> 01:20:51,309
different wavelengths gives you a whole

1809
01:20:48,520 --> 01:20:52,840
new perspective this is why having

1810
01:20:51,310 --> 01:20:59,260

multi-wavelength coverage is so

1811

01:20:52,840 --> 01:21:01,300

important whoops That's not me there we

1812

01:20:59,260 --> 01:21:03,789

go we're back huh look at

1813

01:21:01,300 --> 01:21:06,520

multi-wavelength is so important to give

1814

01:21:03,789 --> 01:21:07,989

you as many views and many ideas on the

1815

01:21:06,520 --> 01:21:11,260

physics that's going for it

1816

01:21:07,989 --> 01:21:13,989

so over its 25 years Hubble has produced

1817

01:21:11,260 --> 01:21:16,720

an amazing panoply of images it has

1818

01:21:13,989 --> 01:21:19,510

looked at planets and stars and nebulae

1819

01:21:16,720 --> 01:21:21,760

and galaxies and all the way across the

1820

01:21:19,510 --> 01:21:24,880

universe but this is a scientific

1821

01:21:21,760 --> 01:21:27,970

telescope and the true measure of Hubble

1822

01:21:24,880 --> 01:21:32,739

of course has to be the science so

1823

01:21:27,970 --> 01:21:34,199

here's a plot we made a back in 2011 to

1824

01:21:32,739 --> 01:21:37,829

celebrate

1825
01:21:34,199 --> 01:21:40,199
the scientific publication the bubbles

1826
01:21:37,829 --> 01:21:42,210
scientific publication record so we have

1827
01:21:40,199 --> 01:21:43,829
the number of refereed science papers

1828
01:21:42,210 --> 01:21:45,659
notice that these are refereed these

1829
01:21:43,829 --> 01:21:47,550
aren't just papers written they have

1830
01:21:45,659 --> 01:21:50,279
been refereed by other scientists and

1831
01:21:47,550 --> 01:21:54,539
over the course of its history these are

1832
01:21:50,279 --> 01:21:56,699
per year okay we're getting up six seven

1833
01:21:54,539 --> 01:22:00,269
hundred papers this plot was produced to

1834
01:21:56,699 --> 01:22:04,349
celebrate the 10,000 refereed scientific

1835
01:22:00,270 --> 01:22:07,620
paper by today we are over 12,000

1836
01:22:04,350 --> 01:22:10,260
refereed scientific papers this is where

1837
01:22:07,619 --> 01:22:12,090
you as taxpayers are getting the bang

1838
01:22:10,260 --> 01:22:15,230
for your buck yes you enjoy the pretty

1839
01:22:12,090 --> 01:22:18,930
pictures but the fact that we have

1840
01:22:15,229 --> 01:22:22,169
changed science across all scales of

1841
01:22:18,930 --> 01:22:27,090
astronomy with this many refereed papers

1842
01:22:22,170 --> 01:22:28,859
is the true value of Hubble so I'm going

1843
01:22:27,090 --> 01:22:34,829
to finish with one of my favorite images

1844
01:22:28,859 --> 01:22:37,559
of Hubble it to me is hopeful it is

1845
01:22:34,829 --> 01:22:40,109
looking up staring out at the universe

1846
01:22:37,560 --> 01:22:43,580
and it has that hopeful feeling to it

1847
01:22:40,109 --> 01:22:46,819
and you may think that after 25 years

1848
01:22:43,579 --> 01:22:51,420
Hubble is old Hubble has been around

1849
01:22:46,819 --> 01:22:54,569
okay it's it's on its downside but I

1850
01:22:51,420 --> 01:22:56,640
gotta tell you that while the

1851
01:22:54,569 --> 01:22:59,729
instruments may be older the telescope

1852
01:22:56,640 --> 01:23:01,829
may be older the scientists and the

1853

01:22:59,729 --> 01:23:05,719
computer programmers and the ability to

1854
01:23:01,829 --> 01:23:08,729
use the telescope has only gotten better

1855
01:23:05,720 --> 01:23:11,250
our understanding of how to use the

1856
01:23:08,729 --> 01:23:13,199
telescope to preserve the batteries how

1857
01:23:11,250 --> 01:23:15,989
to use the telescope to dude use the

1858
01:23:13,199 --> 01:23:19,170
gyros we can go down if we lose for

1859
01:23:15,989 --> 01:23:21,689
gyros we can operate and do 95% of the

1860
01:23:19,170 --> 01:23:24,270
science in to gyro mode we've even

1861
01:23:21,689 --> 01:23:28,139
figured out how to do 60% of the science

1862
01:23:24,270 --> 01:23:31,230
in one gyro mode okay our scheduling has

1863
01:23:28,140 --> 01:23:34,050
gone from approximately two months down

1864
01:23:31,229 --> 01:23:36,329
to less than two weeks for utilizing

1865
01:23:34,050 --> 01:23:40,409
this telescopes we keep gaining

1866
01:23:36,329 --> 01:23:42,510
efficiencies and last year five years

1867
01:23:40,409 --> 01:23:44,609

after servicing mission 4 when the

1868

01:23:42,510 --> 01:23:47,640

warranty on servicing mission 4 had run

1869

01:23:44,609 --> 01:23:47,979

out a top official in this building said

1870

01:23:47,640 --> 01:23:51,400

you know

1871

01:23:47,979 --> 01:23:55,089

what Hubble is actually at its greatest

1872

01:23:51,399 --> 01:23:57,460

power now than it has ever been because

1873

01:23:55,090 --> 01:24:00,400

of the efficiencies we are learning and

1874

01:23:57,460 --> 01:24:02,260

key in utilizing this telescope so I

1875

01:24:00,399 --> 01:24:05,259

have always said I want to see Hubble

1876

01:24:02,260 --> 01:24:07,239

live to 2020 I want to have it still up

1877

01:24:05,260 --> 01:24:09,400

and flying and actively observing when

1878

01:24:07,238 --> 01:24:11,439

the James Webb Space Telescope is up

1879

01:24:09,399 --> 01:24:14,429

that would be fantastic then we could

1880

01:24:11,439 --> 01:24:16,779

have two nasa's flagship missions

1881

01:24:14,430 --> 01:24:19,900

observing one an over the physical light

1882
01:24:16,779 --> 01:24:22,449
one in the infrared to really get pinned

1883
01:24:19,899 --> 01:24:24,759
down ideas because webb will have hubble

1884
01:24:22,449 --> 01:24:28,960
resolution in across the infrared

1885
01:24:24,760 --> 01:24:30,579
spectrum but you know what i'm possibly

1886
01:24:28,960 --> 01:24:32,890
starting to think that maybe we could go

1887
01:24:30,579 --> 01:24:34,988
a bit further right I started giving

1888
01:24:32,890 --> 01:24:37,030
these retrospective talks at Hubble 15

1889
01:24:34,988 --> 01:24:39,219
back when the servicing mission 4 was

1890
01:24:37,029 --> 01:24:41,920
cancelled and I gave one at Hubble 20

1891
01:24:39,220 --> 01:24:44,289
and I'm giving it a Hubble 25 I hope to

1892
01:24:41,920 --> 01:24:48,190
see you all here for Hubble 30 and dare

1893
01:24:44,289 --> 01:24:51,460
I even think about Hubble 35 I don't

1894
01:24:48,189 --> 01:24:53,469
know I just have to say that I in my

1895
01:24:51,460 --> 01:24:55,840
years here have been amazing

1896
01:24:53,470 --> 01:24:58,060
early impressed with the dedication and

1897
01:24:55,840 --> 01:25:03,000
the professionalism of the staff here

1898
01:24:58,060 --> 01:25:06,430
they do an amazing job Hubble has

1899
01:25:03,000 --> 01:25:07,750
transcended astronomy I can say Hubble

1900
01:25:06,430 --> 01:25:10,270
and the public knows what we're talking

1901
01:25:07,750 --> 01:25:11,710
about you can't talk about a particle

1902
01:25:10,270 --> 01:25:14,320
accelerator or a scanning electron

1903
01:25:11,710 --> 01:25:16,390
microscope in the same way all right

1904
01:25:14,319 --> 01:25:18,909
it is part of the public public

1905
01:25:16,390 --> 01:25:21,400
vernacular so it has changed astronomy

1906
01:25:18,909 --> 01:25:23,769
it has changed our view and changed our

1907
01:25:21,399 --> 01:25:25,238
understanding and I hope you will join

1908
01:25:23,770 --> 01:25:27,940
with us this year in celebrating its

1909
01:25:25,238 --> 01:25:31,359
25th anniversary as I like to call it a

1910

01:25:27,939 --> 01:25:33,750
celestial silver celebration thank you

1911
01:25:31,359 --> 01:25:33,750
very much

1912
01:25:53,859 --> 01:25:59,329
okay part of my own rules I have four

1913
01:25:57,350 --> 01:26:01,520
minutes for questions it was like to ask

1914
01:25:59,329 --> 01:26:04,250
any questions otherwise I have to pull

1915
01:26:01,520 --> 01:26:05,990
myself offstage so do we have any

1916
01:26:04,250 --> 01:26:08,270
questions that I can answer I know I

1917
01:26:05,989 --> 01:26:10,219
talked long but I'm sorry there's just

1918
01:26:08,270 --> 01:26:17,600
so much cool stop to joke yes right

1919
01:26:10,220 --> 01:26:19,340
there earth hole has an infinite focus

1920
01:26:17,600 --> 01:26:21,230
it's pointed out into the universe

1921
01:26:19,340 --> 01:26:22,940
the closest thing it's ever observed is

1922
01:26:21,229 --> 01:26:24,979
the moon okay

1923
01:26:22,939 --> 01:26:28,519
Hubble would be useless pointed towards

1924
01:26:24,979 --> 01:26:29,869

Earth and besides the other parts of the

1925

01:26:28,520 --> 01:26:55,910

government have much better ones for

1926

01:26:29,869 --> 01:26:57,800

doing either the Hubble Deep Field or

1927

01:26:55,909 --> 01:26:59,269

the Hubble Ultra Deep Field if you

1928

01:26:57,800 --> 01:27:01,369

thought you saw gravitational lensing in

1929

01:26:59,270 --> 01:27:09,350

the Hubble Deep Field it may have been

1930

01:27:01,369 --> 01:27:11,119

an artifact so you get gravitational

1931

01:27:09,350 --> 01:27:12,380

lensing so the question is how come

1932

01:27:11,119 --> 01:27:14,029

there is gravitational lensing and some

1933

01:27:12,380 --> 01:27:15,859

images you get brevity of lungeing when

1934

01:27:14,029 --> 01:27:18,679

you have a cluster of galaxies providing

1935

01:27:15,859 --> 01:27:20,929

the mass to do the lensing as the mass

1936

01:27:18,680 --> 01:27:22,369

creates the lensing the Hubble Deep

1937

01:27:20,930 --> 01:27:25,400

Field and the Hubble ultra-deep field

1938

01:27:22,369 --> 01:27:27,319

were chosen to look in regions where

1939
01:27:25,399 --> 01:27:29,389
there was there would be no large

1940
01:27:27,319 --> 01:27:31,789
clusters in Matta fact we tried to find

1941
01:27:29,390 --> 01:27:33,230
the emptiest spots in the sky so that we

1942
01:27:31,789 --> 01:27:34,340
can see as far to the universe as

1943
01:27:33,229 --> 01:27:36,529
possible we're trying to get rid of all

1944
01:27:34,340 --> 01:27:39,529
the Milky Way stars although Milky Way

1945
01:27:36,529 --> 01:27:41,479
gasps all of the known galaxies and

1946
01:27:39,529 --> 01:27:43,609
clusters so we didn't look at in those

1947
01:27:41,479 --> 01:27:45,139
regions it actually is an exercise in

1948
01:27:43,609 --> 01:27:53,389
trying to find the most boring part in

1949
01:27:45,140 --> 01:27:54,710
this part of the sky you can find all

1950
01:27:53,390 --> 01:27:55,820
right so he starts out with it if

1951
01:27:54,710 --> 01:27:58,010
there's ever a servicing mission

1952
01:27:55,819 --> 01:27:59,689
approved we have no shuttle program so

1953
01:27:58,010 --> 01:28:02,320
there isn't a servicing mission approved

1954
01:27:59,689 --> 01:28:02,319
so go ahead

1955
01:28:04,600 --> 01:28:11,560
what do you think NASA Institute would

1956
01:28:08,510 --> 01:28:11,560
do actually

1957
01:28:13,300 --> 01:28:18,710
well we are not working on any insight

1958
01:28:16,220 --> 01:28:21,170
so the question is can we improve Hubble

1959
01:28:18,710 --> 01:28:22,970
if there was some impossible chance say

1960
01:28:21,170 --> 01:28:25,250
Elon Musk decided that he it was gonna

1961
01:28:22,970 --> 01:28:29,000
go to Hubble okay I damned he could do

1962
01:28:25,250 --> 01:28:30,649
anything right we would have to develop

1963
01:28:29,000 --> 01:28:32,659
instruments

1964
01:28:30,649 --> 01:28:34,899
whoever would try and service it would

1965
01:28:32,659 --> 01:28:38,479
have to develop a entire suite of

1966
01:28:34,899 --> 01:28:40,339
servicing materials I mean Hubble was

1967

01:28:38,479 --> 01:28:43,039
designed to be serviced in the shuttle

1968
01:28:40,340 --> 01:28:44,900
cargo bay it has the the lazy susan

1969
01:28:43,039 --> 01:28:46,960
there and all the instrumentation and

1970
01:28:44,899 --> 01:28:49,909
everything designed to work with Hubble

1971
01:28:46,960 --> 01:28:53,270
to recreate that would be well nigh

1972
01:28:49,909 --> 01:28:55,250
impossible so that's one thing but in

1973
01:28:53,270 --> 01:28:58,280
order to improve Hubble we would have to

1974
01:28:55,250 --> 01:29:00,289
be developing the repair parts or the

1975
01:28:58,279 --> 01:29:02,829
the new instruments which are not being

1976
01:29:00,289 --> 01:29:06,949
developed and those take several years

1977
01:29:02,829 --> 01:29:10,880
people worked on ACS for five to seven

1978
01:29:06,949 --> 01:29:12,949
years before it launched so it takes

1979
01:29:10,880 --> 01:29:15,079
quite some time to do that so it would

1980
01:29:12,949 --> 01:29:17,269
have to be a concerted effort and would

1981
01:29:15,079 --> 01:29:18,559

have a long long lead time if such a

1982

01:29:17,270 --> 01:29:22,160

thing were possible but I don't think

1983

01:29:18,560 --> 01:29:25,220

leave it is yes what the president plan

1984

01:29:22,159 --> 01:29:27,079

for deorbiting there's no way to the

1985

01:29:25,220 --> 01:29:29,750

present plan for new orbiting Hubble is

1986

01:29:27,079 --> 01:29:31,960

to have a robotic mission during

1987

01:29:29,750 --> 01:29:33,920

servicing mission fourth they they

1988

01:29:31,960 --> 01:29:35,989

installed on the bottom of how well

1989

01:29:33,920 --> 01:29:39,170

something called the SCM soft soft

1990

01:29:35,989 --> 01:29:40,729

capture mechanism so that a robotic

1991

01:29:39,170 --> 01:29:43,220

mission could go up and grapple with

1992

01:29:40,729 --> 01:29:46,369

Hubble and then deorbit it safely oh

1993

01:29:43,220 --> 01:29:48,110

there's the picture is already there yes

1994

01:29:46,369 --> 01:29:49,970

the fixture is already there on Hubble

1995

01:29:48,109 --> 01:29:54,229

now is there a mission plan to do that

1996
01:29:49,970 --> 01:29:58,520
no we'll all of us start crying if that

1997
01:29:54,229 --> 01:30:02,209
happens yes much else we can do right

1998
01:29:58,520 --> 01:30:04,850
now no because we have to do it it

1999
01:30:02,210 --> 01:30:07,460
safely okay after our after space lab in

2000
01:30:04,850 --> 01:30:09,870
the 1970s we learned our lesson we're

2001
01:30:07,460 --> 01:30:13,529
not going to let things come in

2002
01:30:09,869 --> 01:30:16,559
and uncontrolled deorbit right so if we

2003
01:30:13,529 --> 01:30:18,179
can't find some way to do something else

2004
01:30:16,560 --> 01:30:22,050
with Hubble it will have to be deorbited

2005
01:30:18,180 --> 01:30:25,020
safely right you could attach a kind of

2006
01:30:22,050 --> 01:30:26,610
a new boost mechanism on that girl a lot

2007
01:30:25,020 --> 01:30:29,070
of people would love to take Hubble and

2008
01:30:26,609 --> 01:30:30,299
just boost it to a really high orbit and

2009
01:30:29,069 --> 01:30:32,719
let it sit there for a hundred years

2010
01:30:30,300 --> 01:30:34,560
until we figure out something better

2011
01:30:32,720 --> 01:30:36,930
don't know if that's possible either

2012
01:30:34,560 --> 01:30:40,410
okay that's something an Elon Musk would

2013
01:30:36,930 --> 01:30:43,770
probably have you be useful for all

2014
01:30:40,409 --> 01:30:45,720
right one last question I got one last

2015
01:30:43,770 --> 01:30:47,250
question is there somebody from the

2016
01:30:45,720 --> 01:30:51,530
Maryland Space Grant Observatory here

2017
01:30:47,250 --> 01:30:53,130
today to take people across the street

2018
01:30:51,529 --> 01:30:54,599
no there isn't

2019
01:30:53,130 --> 01:30:58,250
what's here in the back did you have a

2020
01:30:54,600 --> 01:30:58,250
question I can apply for that position

2021
01:31:03,140 --> 01:31:13,590
yeah what do you what do you think about

2022
01:31:07,829 --> 01:31:15,359
the movie interstellar I have not seen

2023
01:31:13,590 --> 01:31:17,460
the movie interstellar have a theory of

2024

01:31:15,359 --> 01:31:22,739
everything I have not seen this theory

2025
01:31:17,460 --> 01:31:24,720
of everything I getting ready for the

2026
01:31:22,739 --> 01:31:27,210
astronomical American Astronomical

2027
01:31:24,720 --> 01:31:29,789
Society meeting in Seattle and also I

2028
01:31:27,210 --> 01:31:32,819
promised the IMAX director I work with

2029
01:31:29,789 --> 01:31:35,220
that I would see interstellar on IMAX

2030
01:31:32,819 --> 01:31:37,559
not just go out to any any movie theater

2031
01:31:35,220 --> 01:31:39,390
because Christopher Nolan the director

2032
01:31:37,560 --> 01:31:42,180
loves IMAX and shot a lot of it with

2033
01:31:39,390 --> 01:31:44,190
IMAX and so I promised Tony that I would

2034
01:31:42,180 --> 01:31:46,760
see it on IMAX and I haven't taken the

2035
01:31:44,189 --> 01:31:46,759
time to get there

2036
01:31:53,180 --> 01:31:56,650
you all for coming next