

# Hubble Public Lecture Series

Topic: 25 Years of Hubble

Speaker: Frank Summers,  
Space Telescope Science Institute



1  
00:00:04,519 --> 00:00:02,270  
well then I am dr. Frank summers of the

2  
00:00:07,519 --> 00:00:04,529  
Space Telescope Science Institute and it

3  
00:00:10,549 --> 00:00:07,529  
is my pleasure to welcome you here on

4  
00:00:13,370 --> 00:00:10,559  
this special night as you can see we are

5  
00:00:15,079 --> 00:00:13,380  
one week late it is January 13th and not

6  
00:00:17,390 --> 00:00:15,089  
the second Tuesday not the first Tuesday

7  
00:00:19,820 --> 00:00:17,400  
but you could also see you've got the

8  
00:00:21,980 --> 00:00:19,830  
really cool new seats and the wonderful

9  
00:00:23,990 --> 00:00:21,990  
new carpeting the they finished the

10  
00:00:25,700 --> 00:00:24,000  
auditorium retrofit which is why they

11  
00:00:27,980 --> 00:00:25,710  
didn't let me have the Pope f-series

12  
00:00:29,990 --> 00:00:27,990  
last week which was good because I was

13  
00:00:31,429 --> 00:00:30,000

in Seattle Washington last week for the

14  
00:00:33,799 --> 00:00:31,439  
American Astronomical Society conference

15  
00:00:36,020 --> 00:00:33,809  
so I wouldn't have been here had we had

16  
00:00:37,850 --> 00:00:36,030  
beheld it last week so it's great that

17  
00:00:43,600 --> 00:00:37,860  
both you and I can be here tonight

18  
00:00:47,750 --> 00:00:45,590  
who haven't been here before

19  
00:00:50,450 --> 00:00:47,760  
we have lithographs over all the table

20  
00:00:52,729 --> 00:00:50,460  
over there if you did not get one on

21  
00:00:54,740 --> 00:00:52,739  
your way in grab one on your way out the

22  
00:01:00,139 --> 00:00:54,750  
lithographs are of the galaxy cluster

23  
00:01:02,360 --> 00:01:00,149  
Abell 2744 a very large cluster of

24  
00:01:05,179 --> 00:01:02,370  
galaxies so large it produces

25  
00:01:07,580 --> 00:01:05,189  
gravitational lensing and is being used

26

00:01:09,469 --> 00:01:07,590

as part of the frontier field survey a

27

00:01:12,560 --> 00:01:09,479

little bit of which I will talk about in

28

00:01:15,830 --> 00:01:12,570

my talk tonight speaking of which I am

29

00:01:17,870 --> 00:01:15,840

the speaker tonight giving my 25 years

30

00:01:20,420 --> 00:01:17,880

of Hubble I had actually expected to do

31

00:01:21,859 --> 00:01:20,430

this talk in April because the 25th

32

00:01:24,560 --> 00:01:21,869

anniversary is in April

33

00:01:27,289 --> 00:01:24,570

but we decided to get the festivities

34

00:01:29,569 --> 00:01:27,299

going early right we actually released

35

00:01:32,240 --> 00:01:29,579

the 20 of the the major 25th anniversary

36

00:01:34,580 --> 00:01:32,250

image last Monday at the double-a s

37

00:01:36,440 --> 00:01:34,590

meeting in Seattle and so I said alright

38

00:01:37,670 --> 00:01:36,450

great if we're gonna do that I might as

39

00:01:40,760 --> 00:01:37,680

well go ahead and kick off the year with

40

00:01:43,160 --> 00:01:40,770

the 25 years of Hubble talk anyway it's

41

00:01:45,590 --> 00:01:43,170

also kind of difficult to get a January

42

00:01:47,899 --> 00:01:45,600

speaker nobody wants to commit to doing

43

00:01:49,490 --> 00:01:47,909

the talk after the holidays this has

44

00:01:51,620 --> 00:01:49,500

happened to me every year I've been

45

00:01:55,190 --> 00:01:51,630

running the palm of Ecstasy Rees for 13

46

00:01:56,990 --> 00:01:55,200

years now January and July are generally

47

00:02:00,499 --> 00:01:57,000

the hardest months to get people to to

48

00:02:02,870 --> 00:02:00,509

come in and do the talk ok upcoming we

49

00:02:04,130 --> 00:02:02,880

do have other talks up coming next month

50

00:02:06,830 --> 00:02:04,140

February 3rd

51  
00:02:08,990 --> 00:02:06,840  
Jason Tomlinson has given me one longer

52  
00:02:12,560 --> 00:02:09,000  
talk longer talk titles I've ever been

53  
00:02:15,260 --> 00:02:12,570  
from cosmic birth to living earth the

54  
00:02:18,530 --> 00:02:15,270  
next great Space Telescope beyond jato

55  
00:02:20,360 --> 00:02:18,540  
is T and for those of you who know JWST

56  
00:02:22,640 --> 00:02:20,370  
stands for the James Webb Space

57  
00:02:23,690 --> 00:02:22,650  
Telescope and that's not launching till

58  
00:02:25,730 --> 00:02:23,700  
2018

59  
00:02:27,830 --> 00:02:25,740  
well Jason isn't satisfied with just

60  
00:02:30,410 --> 00:02:27,840  
looking forward a few years he's gonna

61  
00:02:32,450 --> 00:02:30,420  
look even beyond that to the telescopes

62  
00:02:36,470 --> 00:02:32,460  
that will come after the Webb telescope

63  
00:02:38,960 --> 00:02:36,480

on March 3rd we have a very special

64

00:02:43,090 --> 00:02:38,970

event for you we have teamed with the

65

00:02:46,190 --> 00:02:43,100

Baltimore Museum of Art and they have a

66

00:02:50,210 --> 00:02:46,200

guest artist coming in Daria Robledo and

67

00:02:53,780 --> 00:02:50,220

in his exhibit he has several works

68

00:02:56,780 --> 00:02:53,790

inspired by Hubble and he will come and

69

00:02:59,870 --> 00:02:56,790

chat with some folks from here about the

70

00:03:03,680 --> 00:02:59,880

interplay of science and art on March

71

00:03:05,800 --> 00:03:03,690

3rd so that will be a lot of fun if you

72

00:03:08,600 --> 00:03:05,810

want to find out things on our web page

73

00:03:11,720 --> 00:03:08,610

we have this go link up here but as

74

00:03:13,460 --> 00:03:11,730

usual it's easiest if you just use your

75

00:03:15,770 --> 00:03:13,470

favorite search engine look for Hubble

76

00:03:17,900 --> 00:03:15,780

public talks and you should find this

77

00:03:20,420 --> 00:03:17,910

webpage you will have that has a list of

78

00:03:22,460 --> 00:03:20,430

the upcoming lectures information about

79

00:03:25,220 --> 00:03:22,470

other things and also if you see this

80

00:03:28,490 --> 00:03:25,230

link down here this is the archive to

81

00:03:31,729 --> 00:03:28,500

our lectures that have been webcast by

82

00:03:34,490 --> 00:03:31,739

our team here for the past decade we

83

00:03:37,580 --> 00:03:34,500

started doing this archive just before

84

00:03:39,560 --> 00:03:37,590

Hubble's 15th anniversary and so we are

85

00:03:43,100 --> 00:03:39,570

approaching our ten-year anniversary of

86

00:03:45,289 --> 00:03:43,110

webcasts so you've got ten years of cool

87

00:03:46,910 --> 00:03:45,299

talks to catch up on if you haven't been

88

00:03:48,860 --> 00:03:46,920

here before by the way I always like to

89

00:03:51,949 --> 00:03:48,870

ask every now and then alright how many

90

00:03:54,710 --> 00:03:51,959

people have not been here before wow

91

00:03:56,840 --> 00:03:54,720

that's a larger proportion than usual I

92

00:03:59,030 --> 00:03:56,850

guess the 25th anniversary got you got

93

00:04:03,560 --> 00:03:59,040

your attention cool

94

00:04:07,070 --> 00:04:03,570

great love to have that email if you

95

00:04:09,680 --> 00:04:07,080

would like announcements we have a email

96

00:04:11,210 --> 00:04:09,690

list that bike twice a month sends you

97

00:04:14,090 --> 00:04:11,220

an email reminding you of the upcoming

98

00:04:16,310 --> 00:04:14,100

lectures so far we've had a perfect

99

00:04:17,690 --> 00:04:16,320

record of no spam of course now that

100

00:04:19,250 --> 00:04:17,700

this is being webcast I know some

101  
00:04:22,099 --> 00:04:19,260  
hackers gonna go out there and find it

102  
00:04:23,090 --> 00:04:22,109  
and try and ruin that but so far we're

103  
00:04:25,400 --> 00:04:23,100  
just fine

104  
00:04:28,700 --> 00:04:25,410  
we have an email address public lecture

105  
00:04:31,189 --> 00:04:28,710  
at stsci edu which is the perfect place

106  
00:04:32,900 --> 00:04:31,199  
to send an email to sign up for these

107  
00:04:34,490 --> 00:04:32,910  
announcements because we'll have your

108  
00:04:37,610 --> 00:04:34,500  
email return address and can add you to

109  
00:04:41,360 --> 00:04:37,620  
the list you can also use this email for

110  
00:04:43,040 --> 00:04:41,370  
comments and/or questions now the one

111  
00:04:46,520 --> 00:04:43,050  
thing I don't know I'm sorry we have our

112  
00:04:49,550 --> 00:04:46,530  
social media on Facebook and Twitter and

113  
00:04:51,980 --> 00:04:49,560

Google Plus and Pinterest and for me I

114

00:04:55,250 --> 00:04:51,990

have my Facebook and Google Plus and

115

00:04:58,400 --> 00:04:55,260

Twitter if you are so into following

116

00:05:01,580 --> 00:04:58,410

people in that way one thing I don't

117

00:05:03,379 --> 00:05:01,590

know is the observatory as the gentleman

118

00:05:04,760 --> 00:05:03,389

I did not get an email today telling me

119

00:05:06,800 --> 00:05:04,770

whether the observatory would be open

120

00:05:08,719 --> 00:05:06,810

tonight usually they are so this is a

121

00:05:11,300 --> 00:05:08,729

big question mark and has someone down

122

00:05:13,010 --> 00:05:11,310

the front row goes it's really cold but

123

00:05:15,650 --> 00:05:13,020

you know what the cold nights you get

124

00:05:16,850 --> 00:05:15,660

the best seeing okay this is one of the

125

00:05:19,129 --> 00:05:16,860

unfortunate things of being an

126

00:05:23,330 --> 00:05:19,139

astronomer when it's cold and the air is

127

00:05:25,250 --> 00:05:23,340

still you really get better seeing so I

128

00:05:28,190 --> 00:05:25,260

will ask again at the end of the lecture

129

00:05:31,040 --> 00:05:28,200

if there is somebody here to take you

130

00:05:32,540 --> 00:05:31,050

across otherwise you will be able to go

131

00:05:34,400 --> 00:05:32,550

home and have hot chocolate instead of

132

00:05:36,650 --> 00:05:34,410

going in freezing your Tootsie's off in

133

00:05:38,150 --> 00:05:36,660

the observatory dome but anyways thanks

134

00:05:42,200 --> 00:05:38,160

to the Maryland Space Grant Observatory

135

00:05:44,330 --> 00:05:42,210

for providing that every month ok so

136

00:05:46,640 --> 00:05:44,340

this is the point in the talk where I go

137

00:05:50,080 --> 00:05:46,650

to my news from the universe for January

138

00:05:52,520 --> 00:05:50,090

2015 and our top story for tonight is

139

00:05:54,680 --> 00:05:52,530

what are you kidding

140

00:05:58,219 --> 00:05:54,690

I'm doing the main talk and had no time

141

00:06:02,629 --> 00:05:58,229

to gather news stories which i think is

142

00:06:12,260 --> 00:06:02,639

pretty much self-explanatory so we move

143

00:06:14,870 --> 00:06:12,270

on to our featured speaker all right our

144

00:06:22,830 --> 00:06:14,880

featured speaker tonight is myself dr.

145

00:06:26,320 --> 00:06:25,150

Thanks we have so many new people here

146

00:06:28,930 --> 00:06:26,330

tonight I'll give a little bit of my

147

00:06:30,430 --> 00:06:28,940

history I'm an astronomer who got his

148

00:06:34,530 --> 00:06:30,440

undergraduate degree at Virginia Tech

149

00:06:37,110 --> 00:06:34,540

Hokies and of his graduate degrees at

150

00:06:39,520 --> 00:06:37,120

University of California Berkeley I

151

00:06:42,940 --> 00:06:39,530

attended postdocs at Princeton and

152

00:06:46,540 --> 00:06:42,950

Columbia while I was at Columbia I also

153

00:06:48,400 --> 00:06:46,550

was working at the American Museum of

154

00:06:50,770 --> 00:06:48,410

Natural History in New York and I

155

00:06:52,900 --> 00:06:50,780

switched to full-time public outreach

156

00:06:54,910 --> 00:06:52,910

then one of the three curators that

157

00:06:56,920 --> 00:06:54,920

built the Rose Center for Earth and

158

00:06:58,990 --> 00:06:56,930

space in New York the home of the

159

00:07:03,070 --> 00:06:59,000

brand-new Hayden Planetarium in 2000

160

00:07:04,510 --> 00:07:03,080

after building the Rose Center I moved

161

00:07:07,630 --> 00:07:04,520

down here to Baltimore worked with

162

00:07:09,610 --> 00:07:07,640

Hubble and have been here for almost 14

163

00:07:12,730 --> 00:07:09,620

years I'm in the office of public

164

00:07:15,970 --> 00:07:12,740

outreach here and I get to work on all

165

00:07:17,980 --> 00:07:15,980

things Hubble it's really a great job I

166

00:07:20,590 --> 00:07:17,990

get to work in the news stories I get to

167

00:07:22,390 --> 00:07:20,600

work on the website I work on formal

168

00:07:24,040 --> 00:07:22,400

education doing teacher training and

169

00:07:26,410 --> 00:07:24,050

informal education with museums and

170

00:07:28,320 --> 00:07:26,420

planetariums and one of my specialties

171

00:07:31,630 --> 00:07:28,330

that I've developed while here is

172

00:07:34,600 --> 00:07:31,640

scientific visualization having worked

173

00:07:37,030 --> 00:07:34,610

on three IMAX films most notably being

174

00:07:39,700 --> 00:07:37,040

writer science advisor and scientific

175

00:07:42,640 --> 00:07:39,710

visualization supervisor on IMAX Hubble

176

00:07:46,000 --> 00:07:42,650

3d five years ago so ladies and

177

00:07:48,850 --> 00:07:46,010

gentlemen me Rory apologize I'll go do

178

00:07:50,370 --> 00:07:48,860

it again okay thank you thank you that

179

00:07:56,140 --> 00:07:50,380

wonderful and very knowledgeable

180

00:08:00,040 --> 00:07:56,150

introduction I have an impossible task

181

00:08:04,150 --> 00:08:00,050

I'm going to try to cover 25 years of

182

00:08:05,320 --> 00:08:04,160

Hubble in one lecture and as I was

183

00:08:08,410 --> 00:08:05,330

present getting this together

184

00:08:11,050 --> 00:08:08,420

I found all sorts of cool stuff that I

185

00:08:13,690 --> 00:08:11,060

can't include in this talk because I I

186

00:08:15,880 --> 00:08:13,700

spent this afternoon just hiding slides

187

00:08:18,850 --> 00:08:15,890

because there's so much really cool

188

00:08:21,520 --> 00:08:18,860

stuff so I want to say to those of you

189

00:08:23,410 --> 00:08:21,530

who have your favorite Hubble images the

190

00:08:25,090 --> 00:08:23,420

astronomers who might be watching who

191

00:08:27,400 --> 00:08:25,100

have their favourite Hubble observation

192

00:08:30,280 --> 00:08:27,410

probably because they were the PI on it

193

00:08:31,170 --> 00:08:30,290

and those of you who have this this this

194

00:08:32,700 --> 00:08:31,180

idea you're my

195

00:08:34,980 --> 00:08:32,710

just something that was just really

196

00:08:38,040 --> 00:08:34,990

struck you I may not include it in my

197

00:08:40,110 --> 00:08:38,050

talk tonight okay I have not decided on

198

00:08:41,190 --> 00:08:40,120

the best Hubble images I have not

199

00:08:43,290 --> 00:08:41,200

decided on the most scientifically

200

00:08:46,980 --> 00:08:43,300

important Hubble images I have decided

201  
00:08:49,470 --> 00:08:46,990  
on a suite of imagery that tells a story

202  
00:08:53,100 --> 00:08:49,480  
the story that I want to tell you about

203  
00:08:55,320 --> 00:08:53,110  
Hubble's 25 years okay so with that

204  
00:08:58,440 --> 00:08:55,330  
apology out of the way let's go for it

205  
00:09:01,350 --> 00:08:58,450  
now of course you can't do 25 years of

206  
00:09:04,530 --> 00:09:01,360  
Hubble without actually going back 70

207  
00:09:05,579 --> 00:09:04,540  
years 17 years to this man Lyman Spitzer

208  
00:09:09,000 --> 00:09:05,589  
and he was working at the RAND

209  
00:09:12,630 --> 00:09:09,010  
Corporation in 1946 and he wrote a white

210  
00:09:15,360 --> 00:09:12,640  
paper on the idea of a space telescope

211  
00:09:17,510 --> 00:09:15,370  
the benefits to astronomy of having a

212  
00:09:21,720 --> 00:09:17,520  
space telescope

213  
00:09:24,120 --> 00:09:21,730

19:46 that was before we even had the

214

00:09:26,550 --> 00:09:24,130

space age the space age didn't come

215

00:09:28,110 --> 00:09:26,560

until a decade later with the beachball

216

00:09:31,260 --> 00:09:28,120

that was heard around the world

217

00:09:32,519 --> 00:09:31,270

Sputnik that orbited around and started

218

00:09:34,800 --> 00:09:32,529

the beginning of the Space Age

219

00:09:38,160 --> 00:09:34,810

well Sputnik orbiting around the world

220

00:09:41,550 --> 00:09:38,170

had stimulated a mission of the creation

221

00:09:43,350 --> 00:09:41,560

of NASA in 1958 the National Aeronautics

222

00:09:45,780 --> 00:09:43,360

and Space Administration this is their

223

00:09:48,980 --> 00:09:45,790

original logo this is their current

224

00:09:53,070 --> 00:09:48,990

current logo today created in 1958

225

00:09:54,810 --> 00:09:53,080

America gets into space well very soon

226

00:09:57,870 --> 00:09:54,820

thereafter the very beginning of the

227

00:09:59,190 --> 00:09:57,880

Space Age in 1962 this is the National

228

00:10:03,000 --> 00:09:59,200

Academy of Sciences Building in

229

00:10:04,949 --> 00:10:03,010

Washington DC it's just another you know

230

00:10:06,750 --> 00:10:04,959

ceremonial building in DC but it has

231

00:10:08,790 --> 00:10:06,760

this wonderful statue of Einstein out

232

00:10:09,930 --> 00:10:08,800

front so if your kids remember it they

233

00:10:12,870 --> 00:10:09,940

went out probably out and sat on

234

00:10:13,949 --> 00:10:12,880

Einsteins lap when they were there but

235

00:10:16,620 --> 00:10:13,959

the National Academy of Sciences

236

00:10:18,449 --> 00:10:16,630

convened a panel on discussing the

237

00:10:22,440 --> 00:10:18,459

benefits of what they called at the time

238

00:10:25,079 --> 00:10:22,450

a large Space Telescope recommended that

239

00:10:28,650 --> 00:10:25,089

America should move forward on putting a

240

00:10:30,829 --> 00:10:28,660

large telescope into space this of

241

00:10:34,430 --> 00:10:30,839

course ignited all sorts of ideas

242

00:10:37,980 --> 00:10:34,440

everybody has their wonderful ideas and

243

00:10:39,269 --> 00:10:37,990

astronomers are great people but I gotta

244

00:10:40,560 --> 00:10:39,279

say astronomers tend to think that

245

00:10:43,260 --> 00:10:40,570

they're the smartest person in the room

246

00:10:44,430 --> 00:10:43,270

so they tend to want to have their idea

247

00:10:45,780 --> 00:10:44,440

go forward and this

248

00:10:48,360 --> 00:10:45,790

haven't one have their idea horse

249

00:10:51,240 --> 00:10:48,370

there's lots and lots of various ideas

250

00:10:53,070 --> 00:10:51,250

various competing ideas and not just in

251

00:10:57,420 --> 00:10:53,080

the US but around the world

252

00:10:59,490 --> 00:10:57,430

well the logjam was broken in 1976 when

253

00:11:02,520 --> 00:10:59,500

NASA which by now had moved on to this

254

00:11:04,920 --> 00:11:02,530

wonderful worm logo and Issa the

255

00:11:06,480 --> 00:11:04,930

European Space Administration decided

256

00:11:09,420 --> 00:11:06,490

they were going to do a joint proposal

257

00:11:12,150 --> 00:11:09,430

together they pulled their ideas

258

00:11:14,820 --> 00:11:12,160

together and that is what broke the

259

00:11:18,900 --> 00:11:14,830

logjam that's what enabled enough

260

00:11:23,370 --> 00:11:18,910

political will to get Congress to fund

261

00:11:25,290 --> 00:11:23,380

the large Space Telescope in 1977 well

262

00:11:26,910 --> 00:11:25,300

now that you've got funding in a plan

263

00:11:30,900 --> 00:11:26,920

and it moves it moves forward very

264

00:11:34,260 --> 00:11:30,910

quickly in the 1980's the telescope was

265

00:11:37,170 --> 00:11:34,270

built in 1985 it was completed and

266

00:11:39,540 --> 00:11:37,180

construction here it is in Sunnyvale

267

00:11:41,280 --> 00:11:39,550

California and what is happening is it's

268

00:11:43,770 --> 00:11:41,290

undergoing a shake test here here's the

269

00:11:46,110 --> 00:11:43,780

guy in the bunny suit for scale so this

270

00:11:49,220 --> 00:11:46,120

is a human size and this is the size of

271

00:11:52,200 --> 00:11:49,230

the Hubble Space Telescope it was

272

00:11:54,260 --> 00:11:52,210

certified for launch and it was ready to

273

00:11:57,450 --> 00:11:54,270

go up on the space shuttle

274

00:11:59,790 --> 00:11:57,460

unfortunately in 1986 we had the

275

00:12:01,890 --> 00:11:59,800

Challenger accident the space shuttle

276

00:12:06,090 --> 00:12:01,900

program was grounded for several years

277

00:12:10,110 --> 00:12:06,100

and Hubble sat in storage waiting to go

278

00:12:11,910 --> 00:12:10,120

up finally in 1990 Hubble did launch

279

00:12:13,820 --> 00:12:11,920

this is the launch of the Hubble Space

280

00:12:17,040 --> 00:12:13,830

Telescope you'll notice there's another

281

00:12:18,360 --> 00:12:17,050

shuttle on the launch pad here that we

282

00:12:20,550 --> 00:12:18,370

were they were doing some testing there

283

00:12:21,690 --> 00:12:20,560

is only a few times when in the history

284

00:12:23,850 --> 00:12:21,700

of the shuttle program when there have

285

00:12:25,500 --> 00:12:23,860

been two shuttles on the launch pad they

286

00:12:29,070 --> 00:12:25,510

were doing testing here while they

287

00:12:33,090 --> 00:12:29,080

launched Hubble here here as the

288

00:12:34,710 --> 00:12:33,100

wonderful astronaut team that put Hubble

289

00:12:36,690 --> 00:12:34,720

into space you will notice this

290

00:12:37,730 --> 00:12:36,700

gentleman right here does anybody know

291

00:12:41,430 --> 00:12:37,740

who he is

292

00:12:45,870 --> 00:12:41,440

that's Charlie Bolden the current NASA

293

00:12:48,720 --> 00:12:45,880

Administrator he put Hubble into orbit

294

00:12:51,990 --> 00:12:48,730

so we like that we hope that that made

295

00:12:53,850 --> 00:12:52,000

him fond of our telescope here is the

296

00:12:56,220 --> 00:12:53,860

telescope sitting in the shuttle payload

297

00:12:58,020 --> 00:12:56,230

Bay you will notice that it fits very

298

00:13:00,570 --> 00:12:58,030

nicely in the shuttle payload Bay

299

00:13:02,220 --> 00:13:00,580

and that is of course by design simply

300

00:13:04,440 --> 00:13:02,230

because we couldn't make Hubble any

301  
00:13:06,930 --> 00:13:04,450  
larger than what would fit in the

302  
00:13:09,240 --> 00:13:06,940  
shuttle payload Bay okay would we have

303  
00:13:12,000 --> 00:13:09,250  
liked an even larger telescope of course

304  
00:13:13,680 --> 00:13:12,010  
we would were astronomers and bigger is

305  
00:13:15,840 --> 00:13:13,690  
better and when it comes to mirrors and

306  
00:13:17,430 --> 00:13:15,850  
everything but we had a limitation it's

307  
00:13:19,140 --> 00:13:17,440  
always good to have limitations our

308  
00:13:21,240 --> 00:13:19,150  
limitation was the size of the shuttle

309  
00:13:24,540 --> 00:13:21,250  
payload Bay the shuttle payload they

310  
00:13:26,640 --> 00:13:24,550  
also carried aboard an IMAX camera and

311  
00:13:29,880 --> 00:13:26,650  
it got this IMAX camera got this amazing

312  
00:13:36,150 --> 00:13:29,890  
shot of Hubble being set into orbit on

313  
00:13:40,440 --> 00:13:36,160

April 25th 1990 so Hubble is finally up

314

00:13:42,860 --> 00:13:40,450

there from 1946 to 1990 that's all the

315

00:13:47,640 --> 00:13:42,870

precursor history to get Hubble launched

316

00:13:53,160 --> 00:13:47,650

well what do you happens first we get

317

00:13:54,210 --> 00:13:53,170

stories like this NASA's 1.5 billion

318

00:13:55,950 --> 00:13:54,220

blunder

319

00:13:59,850 --> 00:13:55,960

we've got Hubble with a character of mr.

320

00:14:02,190 --> 00:13:59,860

Magoo on even xkcd which is a very geeky

321

00:14:04,920 --> 00:14:02,200

comic strip said Edwin Hubble's car

322

00:14:06,810 --> 00:14:04,930

objects in mirror are something's blur

323

00:14:12,780 --> 00:14:06,820

than they appear or something at that I

324

00:14:16,490 --> 00:14:12,790

can't quite read that so well Hubble's

325

00:14:19,770 --> 00:14:16,500

mirror was ground to a very exact shape

326

00:14:22,470 --> 00:14:19,780

but it was slightly off okay

327

00:14:25,710 --> 00:14:22,480

Hubble after all this precursor history

328

00:14:27,660 --> 00:14:25,720

had a flaw alright and if the flaw was

329

00:14:29,340 --> 00:14:27,670

actually not in the grinding but in the

330

00:14:31,530 --> 00:14:29,350

testing apparatus for the grinding

331

00:14:32,670 --> 00:14:31,540

because from what I understand there

332

00:14:35,280 --> 00:14:32,680

were some pins that were supposed to

333

00:14:37,800 --> 00:14:35,290

drop down into slots for the testing

334

00:14:39,690 --> 00:14:37,810

apparatus and one pin got hooked up a

335

00:14:42,720 --> 00:14:39,700

little bit and so the testing apparatus

336

00:14:45,240 --> 00:14:42,730

was slightly out of shape the testing

337

00:14:48,329 --> 00:14:45,250

apparatus was telling the mirror

338

00:14:51,210 --> 00:14:48,339

polishing to grind it to a very exact

339

00:14:53,610 --> 00:14:51,220

shape but just slightly wrong what did

340

00:14:55,829 --> 00:14:53,620

that mean in practice well it meant that

341

00:14:58,079 --> 00:14:55,839

a star which is supposed to be a point

342

00:15:00,420 --> 00:14:58,089

of light ended up having all this

343

00:15:02,970 --> 00:15:00,430

scattered light around it okay

344

00:15:06,990 --> 00:15:02,980

so Hubble wasn't doing what it was

345

00:15:10,530 --> 00:15:07,000

supposed to but that does not mean it

346

00:15:11,550 --> 00:15:10,540

was the mr. Magoo of telescopes okay all

347

00:15:13,320 --> 00:15:11,560

of those cartoon

348

00:15:16,200 --> 00:15:13,330

all of the things on Johnny Carson at

349

00:15:18,450 --> 00:15:16,210

the time overstated it because Hubble

350

00:15:20,730 --> 00:15:18,460

could still do better things than we

351

00:15:23,190 --> 00:15:20,740

could do from the ground for example

352

00:15:25,560 --> 00:15:23,200

this is an image of a double star from

353

00:15:26,820 --> 00:15:25,570

the ground and any astronomer who looks

354

00:15:29,790 --> 00:15:26,830

at that will tell you the yeah that's a

355

00:15:32,460 --> 00:15:29,800

double star why because if it were a

356

00:15:35,610 --> 00:15:32,470

single star it would be a circle it is

357

00:15:39,210 --> 00:15:35,620

an oval so there must be two sources in

358

00:15:43,160 --> 00:15:39,220

there to create that oval shape Hubble

359

00:15:46,410 --> 00:15:43,170

with the flaw could see it like that

360

00:15:48,030 --> 00:15:46,420

okay now those stars aren't perfect

361

00:15:51,660 --> 00:15:48,040

pinpoints of light like what we like

362

00:15:55,500 --> 00:15:51,670

them to but we can still do science with

363

00:15:57,870 --> 00:15:55,510

the flaw in Hubble's mirror so what did

364

00:15:59,610 --> 00:15:57,880

we do here's another example from the

365

00:16:01,710 --> 00:15:59,620

ground this is what Pluto and Charon

366

00:16:03,510 --> 00:16:01,720

looked at looked like by the way you got

367

00:16:07,950 --> 00:16:03,520

to remember that Karen had only been

368

00:16:09,450 --> 00:16:07,960

discovered in the 1980s okay maybe

369

00:16:11,310 --> 00:16:09,460

people don't remember that Karen was

370

00:16:13,350 --> 00:16:11,320

only discovered in the 1980s this was

371

00:16:15,570 --> 00:16:13,360

brand-new from the ground you could see

372

00:16:17,880 --> 00:16:15,580

there's Pluto and there's Karen with

373

00:16:21,270 --> 00:16:17,890

Hubble you can easily distinguish them

374

00:16:23,760 --> 00:16:21,280

very clearly you can still do things

375

00:16:26,040 --> 00:16:23,770

that not capable from the ground we

376

00:16:28,320 --> 00:16:26,050

could also watch other things okay so

377

00:16:32,340 --> 00:16:28,330

some of the science stories in 1991

378

00:16:34,260 --> 00:16:32,350

there was a major storm on Saturn now

379

00:16:35,730 --> 00:16:34,270

we're used to having Jupiter having lots

380

00:16:37,740 --> 00:16:35,740

of storms we know about the Great Red

381

00:16:39,990 --> 00:16:37,750

Spot and all the storms on Jupiter but

382

00:16:43,079 --> 00:16:40,000

this is Saturn and it only has storms

383

00:16:44,550 --> 00:16:43,089

like this in decades along cycle matter

384

00:16:47,430 --> 00:16:44,560

of fact they tell me the Lord the Lord

385

00:16:48,720 --> 00:16:47,440

the the large storm before this was in

386

00:16:51,360 --> 00:16:48,730

1933

387

00:16:53,790 --> 00:16:51,370

so having Hubble up there to be able to

388

00:16:55,230 --> 00:16:53,800

see it was absolutely amazing this is a

389

00:16:59,730 --> 00:16:55,240

storm that actually stretched all the

390

00:17:02,250 --> 00:16:59,740

way around the planet 1991 we also

391

00:17:05,370 --> 00:17:02,260

showed off Hubble's ability to use fine

392

00:17:07,800 --> 00:17:05,380

resolution to look into star clusters

393

00:17:09,480 --> 00:17:07,810

called globular clusters now in this

394

00:17:10,890 --> 00:17:09,490

ground-based image here you can see that

395

00:17:14,100 --> 00:17:10,900

the core of the globular cluster

396

00:17:16,770 --> 00:17:14,110

Scoville coaster called 47 Tucanae is

397

00:17:18,360 --> 00:17:16,780

basically blown out usually it is so

398

00:17:21,210 --> 00:17:18,370

dense in the cores of these clusters

399

00:17:23,790 --> 00:17:21,220

that from the ground all the stars in

400

00:17:25,319 --> 00:17:23,800

the center are smeared together Hubble

401

00:17:28,499 --> 00:17:25,329

with its fine resolution

402

00:17:31,799 --> 00:17:28,509

can resolve the individual stars and

403

00:17:34,830 --> 00:17:31,809

what it found was a population of stars

404

00:17:36,899 --> 00:17:34,840

we call blue stragglers stars that

405

00:17:39,060 --> 00:17:36,909

because their age should appear much

406

00:17:41,609 --> 00:17:39,070

redder but for some reason they're they

407

00:17:44,609 --> 00:17:41,619

appeared bluer which is younger than

408

00:17:47,399 --> 00:17:44,619

they should have indicating that there

409

00:17:50,279 --> 00:17:47,409

probably were stellar collisions going

410

00:17:52,259 --> 00:17:50,289

on in globular clusters now stars are

411

00:17:54,509 --> 00:17:52,269

just so far apart they never come

412

00:17:56,609 --> 00:17:54,519

anywhere near each other except in the

413

00:17:59,430 --> 00:17:56,619

incredibly dense environments of these

414

00:18:02,700 --> 00:17:59,440

globular clusters showing that you can

415

00:18:07,499 --> 00:18:02,710

actually get two stars colliding in the

416

00:18:10,369 --> 00:18:07,509

cores uncle Aubrey our clusters 1992 we

417

00:18:12,869 --> 00:18:10,379

looked at this galaxy Messier 87 and

418

00:18:15,299 --> 00:18:12,879

Messier 87 is a giant elliptical galaxy

419

00:18:17,970 --> 00:18:15,309

in the center of the Virgo cluster and

420

00:18:20,549 --> 00:18:17,980

you can see that it has a bright source

421

00:18:23,669 --> 00:18:20,559

in the center this is a super massive

422

00:18:25,529 --> 00:18:23,679

black hole supermassive black hole with

423

00:18:28,169 --> 00:18:25,539

approximately a billion times the mass

424

00:18:31,560 --> 00:18:28,179

of our Sun and it's outputting in an

425

00:18:35,129 --> 00:18:31,570

energetic jeta streaming cross inner

426

00:18:38,940 --> 00:18:35,139

stellar space and the details of this

427

00:18:41,879 --> 00:18:38,950

jet were revealed by Hubble in 1992 and

428

00:18:44,460 --> 00:18:41,889

in ways that you could not see from the

429

00:18:46,409 --> 00:18:44,470

ground I am a hammering home that we can

430

00:18:48,330 --> 00:18:46,419

still do good science and those first

431

00:18:52,849 --> 00:18:48,340

tertiary we did do great science in

432

00:18:55,229 --> 00:18:52,859

those first three years also in 1993

433

00:18:57,239 --> 00:18:55,239

amazing thing that I only fully

434

00:18:58,769 --> 00:18:57,249

appreciated when I started when I

435

00:19:02,070 --> 00:18:58,779

studied for this talk

436

00:19:03,720 --> 00:19:02,080

looking at the Andromeda galaxy in the

437

00:19:05,159 --> 00:19:03,730

core of it in the Andromeda galaxy if

438

00:19:08,190 --> 00:19:05,169

you look way down on the core you can

439

00:19:11,340 --> 00:19:08,200

see the center of Andromeda except for

440

00:19:13,859 --> 00:19:11,350

from the ground you are fooled that is

441

00:19:16,590 --> 00:19:13,869

not the core of Andromeda when we

442

00:19:19,009 --> 00:19:16,600

studied it with Hubble we could see that

443

00:19:21,450 --> 00:19:19,019

there are actually two cores in the

444

00:19:23,129 --> 00:19:21,460

Andromeda galaxy and what we had

445

00:19:26,609 --> 00:19:23,139

previously thought was the core of

446

00:19:28,919 --> 00:19:26,619

Andromeda is really a star cluster near

447

00:19:31,349 --> 00:19:28,929

the center of Andromeda and the center

448

00:19:34,200 --> 00:19:31,359

of Andromeda is actually this lighter

449

00:19:35,849 --> 00:19:34,210

spot over here on the right with

450

00:19:37,210 --> 00:19:35,859

Hubble's resolution were able to see

451  
00:19:40,410 --> 00:19:37,220  
into the

452  
00:19:42,580 --> 00:19:40,420  
of that galaxy and find find where the

453  
00:19:45,030 --> 00:19:42,590  
actually we expect a supermassive black

454  
00:19:47,500 --> 00:19:45,040  
hole will be in the core of that galaxy

455  
00:19:49,360 --> 00:19:47,510  
Hubble did a lot of work in its early

456  
00:19:52,090 --> 00:19:49,370  
years studying the Centers of galaxies

457  
00:19:54,280 --> 00:19:52,100  
looking for telltale evidence of these

458  
00:19:56,080 --> 00:19:54,290  
supermassive black holes and basically

459  
00:19:59,020 --> 00:19:56,090  
the answer is we found a supermassive

460  
00:20:03,250 --> 00:19:59,030  
black hole in every large galaxy that we

461  
00:20:07,090 --> 00:20:03,260  
looked at also in 1993 we had this

462  
00:20:10,480 --> 00:20:07,100  
wonderful image of a comet this is comet

463  
00:20:13,510 --> 00:20:10,490

shoemaker-levy 9 which was discovered in

464

00:20:17,110 --> 00:20:13,520

1993 and it was in orbit around Jupiter

465

00:20:20,680 --> 00:20:17,120

and it had broken up into many different

466

00:20:23,160 --> 00:20:20,690

pieces the prediction was that

467

00:20:27,670 --> 00:20:23,170

shoemaker-levy 9 was going to strike

468

00:20:30,640 --> 00:20:27,680

Jupiter but first Hubble got its repair

469

00:20:32,860 --> 00:20:30,650

mission late 1993 this group of

470

00:20:36,220 --> 00:20:32,870

astronauts went up on the space shuttle

471

00:20:39,240 --> 00:20:36,230

to service the service Hubble what they

472

00:20:43,180 --> 00:20:39,250

did is they added in glasses to correct

473

00:20:45,040 --> 00:20:43,190

the flaw in the mirror now optics

474

00:20:46,690 --> 00:20:45,050

they've learned a lot of things in life

475

00:20:47,170 --> 00:20:46,700

for say oh it's not really an exact

476  
00:20:53,380 --> 00:20:47,180  
science

477  
00:20:56,020 --> 00:20:53,390  
so we knew the shape that Hubble's

478  
00:20:58,720 --> 00:20:56,030  
mirror had been ground to and we knew

479  
00:21:02,470 --> 00:20:58,730  
the shape we really wanted so we can

480  
00:21:04,960 --> 00:21:02,480  
design an exact corrector plate to put

481  
00:21:09,760 --> 00:21:04,970  
in the what pathway think of it as some

482  
00:21:11,380 --> 00:21:09,770  
eyeglasses to correct for that now we

483  
00:21:14,470 --> 00:21:11,390  
put in an instrument called co-star

484  
00:21:16,960 --> 00:21:14,480  
corrective optics space telescope axial

485  
00:21:20,050 --> 00:21:16,970  
replacement quite a convoluted acronym

486  
00:21:22,300 --> 00:21:20,060  
but you know it worked to put to correct

487  
00:21:25,060 --> 00:21:22,310  
the optics for the instruments that were

488  
00:21:27,310 --> 00:21:25,070

already installed and this here is what

489

00:21:30,400 --> 00:21:27,320

wide field planetary camera one that's

490

00:21:33,070 --> 00:21:30,410

being taken out and we put in wide field

491

00:21:35,530 --> 00:21:33,080

planetary camera 2 which had the

492

00:21:37,810 --> 00:21:35,540

correction already applied so it didn't

493

00:21:39,400 --> 00:21:37,820

need any high glasses now you got to

494

00:21:41,650 --> 00:21:39,410

recognize that when we're looking at

495

00:21:44,200 --> 00:21:41,660

these wavelengths we're trying to get

496

00:21:45,610 --> 00:21:44,210

down to a tenth at least in a way like

497

00:21:47,710 --> 00:21:45,620

maybe even 100 the way like we're

498

00:21:50,980 --> 00:21:47,720

talking you know 10 nanometer scales

499

00:21:53,680 --> 00:21:50,990

that you have to position these optics

500

00:21:56,290 --> 00:21:53,690

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

501  
00:21:57,760 --> 00:21:56,300  
an optical optical guy I was kind of

502  
00:22:03,730 --> 00:21:57,770  
unsure as to whether this would really

503  
00:22:06,280 --> 00:22:03,740  
work well it did here is the view of a

504  
00:22:11,860 --> 00:22:06,290  
star before co-star was installed and

505  
00:22:13,990 --> 00:22:11,870  
after co-star boom they did it okay I

506  
00:22:16,930 --> 00:22:14,000  
wasn't here at Hubbell at the time but

507  
00:22:19,360 --> 00:22:16,940  
they really nailed it they got that

508  
00:22:22,900 --> 00:22:19,370  
point of light of a star that was

509  
00:22:25,750 --> 00:22:22,910  
expected Hubble net its design

510  
00:22:28,049 --> 00:22:25,760  
specification and now could start doing

511  
00:22:32,680 --> 00:22:28,059  
the science it was intended in

512  
00:22:34,870 --> 00:22:32,690  
particular the imagery the imagery is

513  
00:22:37,180 --> 00:22:34,880

what really show what really was gonna

514

00:22:41,169 --> 00:22:37,190

attract your attention here is the core

515

00:22:47,010 --> 00:22:41,179

of the galaxy m100 in after from with

516

00:22:51,160 --> 00:22:47,020

pick one when we add in the new one boom

517

00:22:54,160 --> 00:22:51,170

quite a difference now Hubble is up to

518

00:22:56,620 --> 00:22:54,170

its full capability we can go back to

519

00:22:59,020 --> 00:22:56,630

looking at Comet shoemaker-levy 9 this

520

00:23:02,169 --> 00:22:59,030

is an image of those pieces of Comet

521

00:23:03,790 --> 00:23:02,179

shoemaker-levy 9 1994 with the repaired

522

00:23:06,040 --> 00:23:03,800

instruments and you can see it's much

523

00:23:09,370 --> 00:23:06,050

clearer but what we really wanted to see

524

00:23:13,090 --> 00:23:09,380

was it was gonna smash into Jupiter now

525

00:23:15,490 --> 00:23:13,100

let's think about it these comet pieces

526  
00:23:16,950 --> 00:23:15,500  
are like one or maybe two kilometers

527  
00:23:20,830 --> 00:23:16,960  
across

528  
00:23:24,520 --> 00:23:20,840  
Jupiter is a hundred and forty thousand

529  
00:23:27,960 --> 00:23:24,530  
kilometers across two kilometers a

530  
00:23:31,390 --> 00:23:27,970  
hundred and forty thousand kilometers

531  
00:23:33,990 --> 00:23:31,400  
it's a pinprick right nothing's gonna

532  
00:23:37,270 --> 00:23:34,000  
happen it was all sorts of debate but

533  
00:23:39,730 --> 00:23:37,280  
fortunately Hubble was looking because

534  
00:23:42,460 --> 00:23:39,740  
something did happen and here's what

535  
00:23:44,790 --> 00:23:42,470  
Hubble saw in visible light this is

536  
00:23:48,040 --> 00:23:44,800  
Jupiter and you see these black marks

537  
00:23:50,440 --> 00:23:48,050  
these are the impact sets where these

538  
00:23:52,000 --> 00:23:50,450

fragments of comets smashed into

539

00:23:55,450 --> 00:23:52,010

Jupiter's atmosphere and basically

540

00:23:58,390 --> 00:23:55,460

exploded and created huge holes in

541

00:24:00,880 --> 00:23:58,400

Jupiter's atmosphere every telescope in

542

00:24:03,340 --> 00:24:00,890

the world was watching but only Hubble

543

00:24:04,659 --> 00:24:03,350

was above Earth's atmosphere and could

544

00:24:07,359 --> 00:24:04,669

also watch

545

00:24:10,330 --> 00:24:07,369

in ultraviolet light where you can see

546

00:24:11,619 --> 00:24:10,340

the impact sites much more clearly by

547

00:24:14,169 --> 00:24:11,629

the way this is not an impact site

548

00:24:16,450 --> 00:24:14,179

that's just a shadow of a moon okay one

549

00:24:18,489 --> 00:24:16,460

of the Galilean moons so you could an

550

00:24:20,139 --> 00:24:18,499

ultraviolet light I know you all think

551  
00:24:21,310 --> 00:24:20,149  
that when you go out in the summer you

552  
00:24:22,960 --> 00:24:21,320  
have to put on the suntan lotion because

553  
00:24:25,749 --> 00:24:22,970  
lots of ultraviolet light is out is

554  
00:24:27,009 --> 00:24:25,759  
coming down almost no volts or violet

555  
00:24:38,560 --> 00:24:27,019  
light gets through our atmosphere in

556  
00:24:46,659 --> 00:24:41,379  
in terms of seeing the observations of

557  
00:24:48,580 --> 00:24:46,669  
Comet shoemaker-levy 9 1995 and right

558  
00:24:51,700 --> 00:24:48,590  
out of the gate we're gonna hit one of

559  
00:24:53,979 --> 00:24:51,710  
our best images ever this is the

560  
00:24:57,310 --> 00:24:53,989  
so-called pillars of creation the

561  
00:25:00,340 --> 00:24:57,320  
pillars in the Eagle Nebula and to this

562  
00:25:04,090 --> 00:25:00,350  
day it is one of our most popular images

563  
00:25:06,989 --> 00:25:04,100

if not the most popular I gotta say the

564

00:25:09,669 --> 00:25:06,999

public just loves ionization fronts ok

565

00:25:13,869 --> 00:25:09,679

what is an ionization front you ask well

566

00:25:15,249 --> 00:25:13,879

I'll answer that so up there a couple

567

00:25:17,560 --> 00:25:15,259

floors above us there are some really

568

00:25:20,830 --> 00:25:17,570

really bright stars and they have

569

00:25:23,889 --> 00:25:20,840

high-energy radiation and stellar winds

570

00:25:25,299 --> 00:25:23,899

streaming away from them that energy is

571

00:25:27,940 --> 00:25:25,309

coming down like this

572

00:25:29,680 --> 00:25:27,950

hitting these dense regions at the tops

573

00:25:32,109 --> 00:25:29,690

of the pillars and you can see the

574

00:25:34,629 --> 00:25:32,119

bright light around them as it takes

575

00:25:37,180 --> 00:25:34,639

that dark gas dense gas this molecular

576

00:25:40,029 --> 00:25:37,190

gas and ionizes it the energy is

577

00:25:42,479 --> 00:25:40,039

transferred to that dark gas and it

578

00:25:45,279 --> 00:25:42,489

ionizes and you create these pillars

579

00:25:48,279 --> 00:25:45,289

because the winds are streaming down and

580

00:25:51,399 --> 00:25:48,289

in here it's not necessarily dense gas

581

00:25:54,460 --> 00:25:51,409

it is just in the shadow of these dense

582

00:25:56,919 --> 00:25:54,470

regions at the tops of the pillars and

583

00:25:59,409 --> 00:25:56,929

creates this great silhouette that's

584

00:26:04,899 --> 00:25:59,419

great contrast against the background of

585

00:26:06,909 --> 00:26:04,909

the image of the nebula also in 1995 the

586

00:26:08,889 --> 00:26:06,919

exact matter fact two weeks after that

587

00:26:11,080 --> 00:26:08,899

image was released another of our

588

00:26:13,599 --> 00:26:11,090

amazing images was released this one of

589

00:26:16,149 --> 00:26:13,609

the trapezium region in the Orion Nebula

590

00:26:17,269 --> 00:26:16,159

center of the Orion Nebula another star

591

00:26:19,549 --> 00:26:17,279

forming Reed

592

00:26:22,580 --> 00:26:19,559

and in the Orion Nebula there are

593

00:26:25,070 --> 00:26:22,590

thousands of new stars being born and

594

00:26:27,529 --> 00:26:25,080

plus the center stars and here are also

595

00:26:30,980 --> 00:26:27,539

blowing off their winds such that this

596

00:26:32,990 --> 00:26:30,990

object down here LLO or yonus you can

597

00:26:34,820 --> 00:26:33,000

see has a bow shock around it the wind

598

00:26:38,029 --> 00:26:34,830

coming down from these bright stars

599

00:26:40,430 --> 00:26:38,039

creates a bow shock around it someone in

600

00:26:41,810 --> 00:26:40,440

right close to the trapezium stars you

601  
00:26:44,990 --> 00:26:41,820  
can see that the bow shock is wrapped

602  
00:26:47,149 --> 00:26:45,000  
around to make a tadpole alright this is

603  
00:26:49,580 --> 00:26:47,159  
the wind streaming past the material

604  
00:26:52,639 --> 00:26:49,590  
around this forming solar forming star

605  
00:26:55,580 --> 00:26:52,649  
creating a sort of wind sock effect and

606  
00:26:58,909 --> 00:26:55,590  
what's really cool is that if you look

607  
00:27:02,810 --> 00:26:58,919  
in detail you can see these dust disks

608  
00:27:06,950 --> 00:27:02,820  
around brand-new stars and these dusty

609  
00:27:10,250 --> 00:27:06,960  
discs are where the planets are forming

610  
00:27:14,480 --> 00:27:10,260  
in a new solar system within the Orion

611  
00:27:18,320 --> 00:27:14,490  
Nebula we get to see other solar systems

612  
00:27:19,220 --> 00:27:18,330  
in formation and Hubble was the first to

613  
00:27:22,549 --> 00:27:19,230

be able to give us the kind of

614

00:27:27,019 --> 00:27:22,559

resolution to see this amazing detail

615

00:27:30,470 --> 00:27:27,029

here 1996 we go from star birth to star

616

00:27:33,259 --> 00:27:30,480

death this is the star eita Carina and

617

00:27:36,289 --> 00:27:33,269

it is a hundred solar mass star maybe

618

00:27:39,409 --> 00:27:36,299

150 solar mass star and it is not just

619

00:27:41,990 --> 00:27:39,419

being born but instead we believe it's

620

00:27:44,570 --> 00:27:42,000

on its way to die this is what we

621

00:27:46,669 --> 00:27:44,580

consider to be a pre supernova star a

622

00:27:49,789 --> 00:27:46,679

star at the end of its life that we

623

00:27:51,980 --> 00:27:49,799

expect to explode sometime in the next

624

00:27:54,320 --> 00:27:51,990

few million years but what we can see

625

00:27:56,210 --> 00:27:54,330

here is an amazing detail of what's

626  
00:27:58,759 --> 00:27:56,220  
called the homunculus these big lobes

627  
00:28:00,620 --> 00:27:58,769  
these bubbles the stars in the center

628  
00:28:02,450 --> 00:28:00,630  
here you can see this incredible bubble

629  
00:28:05,269 --> 00:28:02,460  
being blown from both directions these

630  
00:28:08,840 --> 00:28:05,279  
bipolar bubbles and then outbursts from

631  
00:28:10,299 --> 00:28:08,850  
a tack are going out and again detail

632  
00:28:13,340 --> 00:28:10,309  
that we had never seen before

633  
00:28:18,039 --> 00:28:13,350  
we also in seeing amazing detail

634  
00:28:20,029 --> 00:28:18,049  
measured the first size of a star now

635  
00:28:21,680 --> 00:28:20,039  
you may think about this all right well

636  
00:28:24,019 --> 00:28:21,690  
we can see the Sun and it's it's a half

637  
00:28:25,730 --> 00:28:24,029  
a degree across okay so you know we can

638  
00:28:30,259 --> 00:28:25,740

see the size of that star but every

639

00:28:30,700 --> 00:28:30,269

other star is so far away it appears as

640

00:28:32,970 --> 00:28:30,710

a

641

00:28:36,250 --> 00:28:32,980

of light even in our best telescopes

642

00:28:39,250 --> 00:28:36,260

well with Hubble we're able to make out

643

00:28:42,039 --> 00:28:39,260

the size of baitul juice this is the

644

00:28:47,019 --> 00:28:42,049

shoulder of Orion here it is a red

645

00:28:50,289 --> 00:28:47,029

supergiant star that is so large that if

646

00:28:53,260 --> 00:28:50,299

it were in our solar system it would be

647

00:28:56,049 --> 00:28:53,270

larger than Earth's orbit it would be

648

00:29:00,070 --> 00:28:56,059

larger than Jupiter's orbit Mercury

649

00:29:02,909 --> 00:29:00,080

Venus Earth Mars the asteroid belt and

650

00:29:06,070 --> 00:29:02,919

Jupiter would all be orbiting inside

651  
00:29:08,440 --> 00:29:06,080  
fatal juice were where our son is

652  
00:29:12,210 --> 00:29:08,450  
and with Hubble we're able to measure

653  
00:29:16,060 --> 00:29:12,220  
the size of that star the first one ever

654  
00:29:18,399 --> 00:29:16,070  
well 1997 brought servicing mission two

655  
00:29:20,409 --> 00:29:18,409  
and this is the amazing crew that went

656  
00:29:24,010 --> 00:29:20,419  
up to service Hubble on the second

657  
00:29:26,320 --> 00:29:24,020  
servicing mission servicing mission two

658  
00:29:27,610 --> 00:29:26,330  
added in two new instruments the near

659  
00:29:29,919 --> 00:29:27,620  
infrared camera multi-object

660  
00:29:31,360 --> 00:29:29,929  
spectrograph otherwise known as Nick

661  
00:29:33,730 --> 00:29:31,370  
Moss which added to the infrared

662  
00:29:36,399 --> 00:29:33,740  
capabilities of Hubble and the Space

663  
00:29:38,649 --> 00:29:36,409

Telescope imaging spectrograph which

664

00:29:42,159 --> 00:29:38,659

both of them are spectrum spectrographs

665

00:29:45,510 --> 00:29:42,169

but they also add to this adds to the

666

00:29:49,600 --> 00:29:45,520

ultraviolet capabilities of Hubble that

667

00:29:52,419 --> 00:29:49,610

mission again was success and this may

668

00:29:54,639 --> 00:29:52,429

look to you like a picture of Mars it's

669

00:29:57,250 --> 00:29:54,649

not this is something I discovered

670

00:29:58,960 --> 00:29:57,260

actually this morning as I was going

671

00:30:01,060 --> 00:29:58,970

through making sure I had all the really

672

00:30:03,180 --> 00:30:01,070

cool images this is one I didn't know

673

00:30:08,139 --> 00:30:03,190

about this is not Mars

674

00:30:10,899 --> 00:30:08,149

this is Jupiter's moon Io and what you

675

00:30:13,840 --> 00:30:10,909

see on the limb of Jupiter's moon looks

676  
00:30:16,560 --> 00:30:13,850  
like a blurry thing which is just an

677  
00:30:19,389 --> 00:30:16,570  
error right no it's not

678  
00:30:22,210 --> 00:30:19,399  
Jupiter's moon Io is the most volcanic

679  
00:30:24,610 --> 00:30:22,220  
object in the solar system there are an

680  
00:30:28,060 --> 00:30:24,620  
average of seven volcanoes going off at

681  
00:30:31,029 --> 00:30:28,070  
any one time and the volcanic plumes

682  
00:30:36,220 --> 00:30:31,039  
reach so high they can actually be seen

683  
00:30:39,399 --> 00:30:36,230  
off the limb of Io and I did not know

684  
00:30:42,850 --> 00:30:39,409  
until today that Hubble actually was

685  
00:30:44,509 --> 00:30:42,860  
able to see a volcanic plume on Io from

686  
00:30:46,999 --> 00:30:44,519  
Earth I got

687  
00:30:49,639 --> 00:30:47,009  
say this compares very well to the New

688  
00:30:52,279 --> 00:30:49,649

Horizons mission and one of my favorite

689

00:30:56,239 --> 00:30:52,289

images in all of astronomy this is the

690

00:30:58,609 --> 00:30:56,249

volcano tabash star on Io captured by

691

00:31:00,259 --> 00:30:58,619

the New Horizons mission as it was

692

00:31:05,119 --> 00:31:00,269

getting a gravity assist flying by

693

00:31:07,940 --> 00:31:05,129

Jupiter so this is an in situ at Jupiter

694

00:31:10,820 --> 00:31:07,950

image whereas Hubble was able to

695

00:31:13,579 --> 00:31:10,830

actually see a plume as well being here

696

00:31:15,829 --> 00:31:13,589

at Earth and I've been working with

697

00:31:18,049 --> 00:31:15,839

Hubble for 13 years and that sort of

698

00:31:22,039 --> 00:31:18,059

surprised me that they were able to get

699

00:31:25,339 --> 00:31:22,049

that kind of that kind of observation in

700

00:31:27,799 --> 00:31:25,349

1997 we also looked at a favorite pair

701  
00:31:30,169 --> 00:31:27,809  
of galaxies for astronomers called the

702  
00:31:31,669 --> 00:31:30,179  
antennae galaxies and you might be able

703  
00:31:32,839 --> 00:31:31,679  
to understand why they were called the

704  
00:31:36,440 --> 00:31:32,849  
antennae because they have these big

705  
00:31:38,839 --> 00:31:36,450  
long plumes sticking out from these twin

706  
00:31:40,459 --> 00:31:38,849  
centers well looking at it with Hubble

707  
00:31:43,219 --> 00:31:40,469  
these are two galaxies that are

708  
00:31:45,409 --> 00:31:43,229  
colliding all right and with Hubble

709  
00:31:47,810 --> 00:31:45,419  
we're able to look into the detail into

710  
00:31:51,319 --> 00:31:47,820  
the core of this and you see all these

711  
00:31:54,019 --> 00:31:51,329  
blue star clusters revealing the intense

712  
00:31:56,869 --> 00:31:54,029  
star formation that happens when

713  
00:31:59,539 --> 00:31:56,879

galaxies collide and in particular what

714

00:32:00,799 --> 00:31:59,549

Hubble was able to discover was if it's

715

00:32:04,039 --> 00:32:00,809

resolution it was able to see that these

716

00:32:06,379 --> 00:32:04,049

are not just star clusters but what the

717

00:32:09,319 --> 00:32:06,389

astronomer called super star clusters

718

00:32:13,190 --> 00:32:09,329

very very large clusters of stars that

719

00:32:17,119 --> 00:32:13,200

are formed when galaxies collide seen in

720

00:32:20,289 --> 00:32:17,129

the resolution with with the map Hubble

721

00:32:23,299 --> 00:32:20,299

looked at the antennae galaxies in

722

00:32:26,509 --> 00:32:23,309

1997-1998 flexed his muscle using the

723

00:32:29,269 --> 00:32:26,519

ultraviolet and stiff this is Saturn and

724

00:32:32,239 --> 00:32:29,279

you can see the aurora here on Saturn

725

00:32:34,699 --> 00:32:32,249

both in the south and up in the north

726  
00:32:35,989 --> 00:32:34,709  
now Saturn has Aurora like Earth does

727  
00:32:37,430 --> 00:32:35,999  
the Northern Lights

728  
00:32:39,229 --> 00:32:37,440  
and the southern lights or aurora

729  
00:32:43,789 --> 00:32:39,239  
borealis in the Aurora Australis

730  
00:32:45,649 --> 00:32:43,799  
however Saturn's Aurora is not visible

731  
00:32:48,259 --> 00:32:45,659  
with the invisible is not seen in

732  
00:32:50,899 --> 00:32:48,269  
visible light it is only seen in

733  
00:32:53,889 --> 00:32:50,909  
ultraviolet light so again you need a

734  
00:32:55,940 --> 00:32:53,899  
Space Telescope and the ultraviolet

735  
00:32:57,130 --> 00:32:55,950  
capabilities on Hubble were improved by

736  
00:32:59,799 --> 00:32:57,140  
a factor of 10

737  
00:33:03,010 --> 00:32:59,809  
with the addition of stiffers enabling us

738  
00:33:05,230 --> 00:33:03,020

to see amazing detail in the Aurora on

739

00:33:07,750 --> 00:33:05,240

Saturn but also by the way the Aurora on

740

00:33:11,710 --> 00:33:07,760

Jupiter also visible in ultraviolet

741

00:33:14,020 --> 00:33:11,720

light in the infrared we looked toward

742

00:33:14,740 --> 00:33:14,030

Uranus now if you've seen any pictures

743

00:33:18,340 --> 00:33:14,750

of Uranus

744

00:33:21,669 --> 00:33:18,350

it's pretty boring it's a pretty blasé

745

00:33:24,820 --> 00:33:21,679

nothing of a planet that's viewing it

746

00:33:26,830 --> 00:33:24,830

using visible light in infrared light we

747

00:33:29,440 --> 00:33:26,840

were actually able to see storms on

748

00:33:32,470 --> 00:33:29,450

Uranus we're able to get the highlights

749

00:33:36,070 --> 00:33:32,480

of the Rings around Uranus and multiple

750

00:33:38,500 --> 00:33:36,080

of many several of its moons taking

751  
00:33:41,530 --> 00:33:38,510  
transforming Uranus from a rather bland

752  
00:33:43,180 --> 00:33:41,540  
greenish planet to something with with a

753  
00:33:48,310 --> 00:33:43,190  
lot more structure seeing a lot more

754  
00:33:51,280 --> 00:33:48,320  
detail in the atmosphere of Uranus 1998

755  
00:33:53,380 --> 00:33:51,290  
is also noticeable note notable because

756  
00:33:56,140 --> 00:33:53,390  
it was the start of the Hubble heritage

757  
00:33:58,960 --> 00:33:56,150  
project Hubble heritage project is a

758  
00:34:02,289 --> 00:33:58,970  
project to go through the Hubble archive

759  
00:34:04,720 --> 00:34:02,299  
and find the best Hubble images that

760  
00:34:07,000 --> 00:34:04,730  
haven't been released because of press

761  
00:34:09,250 --> 00:34:07,010  
not all the pretty pictures have a good

762  
00:34:10,180 --> 00:34:09,260  
press have have have great science that

763  
00:34:12,070 --> 00:34:10,190

they're worthy of a press release

764

00:34:14,020 --> 00:34:12,080

there's a lot of really cool stuff in

765

00:34:16,899 --> 00:34:14,030

the Hubble archive and this project was

766

00:34:19,899 --> 00:34:16,909

started to go back and find those and in

767

00:34:22,240 --> 00:34:19,909

fact has blossomed into a major source

768

00:34:24,639 --> 00:34:22,250

of really cool Hubble images such that

769

00:34:27,099 --> 00:34:24,649

they often get some as time assigned to

770

00:34:29,740 --> 00:34:27,109

them in order to take really cool images

771

00:34:32,169 --> 00:34:29,750

for specifics for special special

772

00:34:33,520 --> 00:34:32,179

releases including our Hubble 25th

773

00:34:34,530 --> 00:34:33,530

anniversary image which I'll show you

774

00:34:39,369 --> 00:34:34,540

later

775

00:34:41,800 --> 00:34:39,379

now Edwin Hubble was notable know they

776

00:34:44,080 --> 00:34:41,810

had two major scientific compliments

777

00:34:46,450 --> 00:34:44,090

that people associated with him one is

778

00:34:49,300 --> 00:34:46,460

this observation of the Andromeda galaxy

779

00:34:52,510 --> 00:34:49,310

and really not the and he was looking

780

00:34:54,040 --> 00:34:52,520

these ends here indicate nobody okay he

781

00:34:56,020 --> 00:34:54,050

was looking for stars that would flash

782

00:34:59,400 --> 00:34:56,030

you're looking for nova in the andromeda

783

00:35:02,109 --> 00:34:59,410

galaxy but he found this one up here and

784

00:35:06,730 --> 00:35:02,119

actually found that it was a variable

785

00:35:08,650 --> 00:35:06,740

star and variable stars are special at

786

00:35:09,940 --> 00:35:08,660

least the Cepheid variable stars are

787

00:35:12,400 --> 00:35:09,950

special in

788

00:35:13,870 --> 00:35:12,410

the period of their variability the

789

00:35:17,410 --> 00:35:13,880

amount of time it takes them to brighten

790

00:35:19,990 --> 00:35:17,420

and dim and brighten again is related to

791

00:35:22,480 --> 00:35:20,000

their absolute brightness and if you

792

00:35:24,220 --> 00:35:22,490

know their absolute brightness and you

793

00:35:27,820 --> 00:35:24,230

can compare to the apparent brightness

794

00:35:31,680 --> 00:35:27,830

you can calculate distances and Hubble's

795

00:35:34,750 --> 00:35:31,690

second major second second major

796

00:35:37,840 --> 00:35:34,760

discovery was that the distances to

797

00:35:38,770 --> 00:35:37,850

various galaxies were proportional to

798

00:35:40,690 --> 00:35:38,780

their redshift

799

00:35:43,720 --> 00:35:40,700

now the redshift is a measure of their

800

00:35:46,510 --> 00:35:43,730

parent motion away from the Milky Way

801  
00:35:48,340 --> 00:35:46,520  
all right when we look out into space we

802  
00:35:50,890 --> 00:35:48,350  
see that all galaxies appear to be

803  
00:35:54,820 --> 00:35:50,900  
receding from us and interpret this as

804  
00:35:58,510 --> 00:35:54,830  
the expansion of the universe so these

805  
00:36:01,840 --> 00:35:58,520  
are Hubble's great observations but you

806  
00:36:04,990 --> 00:36:01,850  
know what Edwin Hubble didn't have a

807  
00:36:06,880 --> 00:36:05,000  
hubble space telescope so he actually

808  
00:36:09,670 --> 00:36:06,890  
got the slope of this line pretty wrong

809  
00:36:12,520 --> 00:36:09,680  
he actually used the wrong type of

810  
00:36:15,190 --> 00:36:12,530  
Cepheid variable and got his numbers

811  
00:36:17,320 --> 00:36:15,200  
kind of well they had a lot of error in

812  
00:36:19,900 --> 00:36:17,330  
them but for the time they were great

813  
00:36:22,590 --> 00:36:19,910

but we had the Hubble and one of the key

814

00:36:27,280 --> 00:36:22,600

projects for the hubble space telescope

815

00:36:29,800 --> 00:36:27,290

was to nail down tighten up the

816

00:36:31,630 --> 00:36:29,810

expansion rate of the universe because

817

00:36:33,910 --> 00:36:31,640

at the time of Hubble's launched there

818

00:36:35,740 --> 00:36:33,920

was a camp that said no the universe is

819

00:36:37,480 --> 00:36:35,750

expanding at 50 kilometers per second

820

00:36:38,980 --> 00:36:37,490

per megaparsec you don't need to know

821

00:36:40,870 --> 00:36:38,990

what that means just you know that this

822

00:36:42,520 --> 00:36:40,880

was a 50 camp then there was another

823

00:36:44,560 --> 00:36:42,530

camp that said it was at a hundred

824

00:36:46,330 --> 00:36:44,570

kilometers per megaparsec okay

825

00:36:49,480 --> 00:36:46,340

kilometers per second per megaparsec and

826

00:36:51,160 --> 00:36:49,490

they were off by a factor of two all

827

00:36:53,830 --> 00:36:51,170

right and each of them had really good

828

00:36:55,990 --> 00:36:53,840

reasons for believing them so what we

829

00:36:58,360 --> 00:36:56,000

did with Hubble is we used those same

830

00:37:00,940 --> 00:36:58,370

Cepheid variables and we measured those

831

00:37:02,620 --> 00:37:00,950

Cepheid variables to all of as many

832

00:37:04,900 --> 00:37:02,630

local galaxies as we could using

833

00:37:07,050 --> 00:37:04,910

Hubble's resolution then of course

834

00:37:09,820 --> 00:37:07,060

measured the redshift for them and

835

00:37:13,330 --> 00:37:09,830

recalibrated a brand new Hubble diagram

836

00:37:15,120 --> 00:37:13,340

and this is a project that could not

837

00:37:17,820 --> 00:37:15,130

proceed during the first three years

838

00:37:19,980 --> 00:37:17,830

basically you needed the really

839

00:37:22,470 --> 00:37:19,990

the exquisite resolution that Hubble had

840

00:37:24,150 --> 00:37:22,480

after servicing mission 1 in order to

841

00:37:26,430 --> 00:37:24,160

proceed this so it took longer than we

842

00:37:29,310 --> 00:37:26,440

expected but after eight years of hard

843

00:37:32,460 --> 00:37:29,320

work and measuring the distances to 18

844

00:37:35,030 --> 00:37:32,470

different galaxies in the local area the

845

00:37:37,650 --> 00:37:35,040

HST key project on the Hubble constant

846

00:37:39,840 --> 00:37:37,660

finally released their result saying

847

00:37:44,310 --> 00:37:39,850

that the average in the local universe

848

00:37:46,140 --> 00:37:44,320

was a value of 70 plus or minus 10% and

849

00:37:47,700 --> 00:37:46,150

I know that doesn't sound sound sound

850

00:37:50,070 --> 00:37:47,710

like much but for an astronomers who are

851

00:37:53,430 --> 00:37:50,080

used to a factor of two to get it down

852

00:37:55,760 --> 00:37:53,440

to 10% was amazing this was the

853

00:37:58,260 --> 00:37:55,770

beginning of our precision cosmology

854

00:38:00,750 --> 00:37:58,270

when our cosmological models which when

855

00:38:02,850 --> 00:38:00,760

I was in graduate school were wildly

856

00:38:04,260 --> 00:38:02,860

variable and you could you could take a

857

00:38:07,110 --> 00:38:04,270

lot of different parameters and still

858

00:38:09,920 --> 00:38:07,120

fit the data finally we start getting

859

00:38:12,330 --> 00:38:09,930

precision we follow it up with the the

860

00:38:14,940 --> 00:38:12,340

Cosmic Microwave Background observations

861

00:38:18,300 --> 00:38:14,950

and such and over the course of Hubble's

862

00:38:20,400 --> 00:38:18,310

lifetime we have gone from from a lot of

863

00:38:22,650 --> 00:38:20,410

uncertainty in our models down to a very

864

00:38:26,670 --> 00:38:22,660

tightly fit model this is one of the key

865

00:38:28,260 --> 00:38:26,680

points in that transition another really

866

00:38:30,210 --> 00:38:28,270

cool thing that caught my eye I wasn't

867

00:38:33,810 --> 00:38:30,220

at Hubble at the time I was up in New

868

00:38:38,340 --> 00:38:33,820

York was this image right here HR 47 96

869

00:38:40,530 --> 00:38:38,350

a now what this is is a is an image

870

00:38:43,560 --> 00:38:40,540

where the light from the star has been

871

00:38:45,180 --> 00:38:43,570

blocked by an occulting spot okay it's

872

00:38:46,740 --> 00:38:45,190

like when you're looking at the Sun and

873

00:38:48,630 --> 00:38:46,750

you go oh I want to block that right

874

00:38:51,300 --> 00:38:48,640

well that's all we do in astronomy we

875

00:38:54,290 --> 00:38:51,310

block the light of the star in order to

876

00:38:57,390 --> 00:38:54,300

see the faint material around it and

877

00:38:59,700 --> 00:38:57,400

this is on the scale of the distance to

878

00:39:03,990 --> 00:38:59,710

that star the diameter of Neptune's

879

00:39:06,000 --> 00:39:04,000

orbit we had in the 1990s just begun

880

00:39:09,900 --> 00:39:06,010

discovered the Kuiper belt in our own

881

00:39:13,170 --> 00:39:09,910

solar system and when I we saw 47 96 a

882

00:39:15,060 --> 00:39:13,180

we pointed that and said damn that looks

883

00:39:18,380 --> 00:39:15,070

like we're seeing a Kuiper belt in

884

00:39:21,930 --> 00:39:18,390

another solar system around another star

885

00:39:23,340 --> 00:39:21,940

starting to see and in this one HD one

886

00:39:27,260 --> 00:39:23,350

four one five six nine

887

00:39:30,150 --> 00:39:27,270

you see rings but you also see a gap and

888

00:39:32,190 --> 00:39:30,160

gaps are really important because

889

00:39:35,100 --> 00:39:32,200

the only way a gap opens up is if

890

00:39:37,530 --> 00:39:35,110

there's a gravitational force pulling to

891

00:39:39,300 --> 00:39:37,540

create that gap it doesn't mean that

892

00:39:41,070 --> 00:39:39,310

there's a planet inside the gap there

893

00:39:43,650 --> 00:39:41,080

could be but there could also be a

894

00:39:46,110 --> 00:39:43,660

planet inside inside or outside that

895

00:39:49,050 --> 00:39:46,120

gravitational resonance is opening up

896

00:39:51,000 --> 00:39:49,060

that gap we're beginning to not only see

897

00:39:52,620 --> 00:39:51,010

planetary systems in formation but to

898

00:39:54,770 --> 00:39:52,630

start to see some of the details of

899

00:39:59,010 --> 00:39:54,780

planetary systems

900

00:40:02,850 --> 00:39:59,020

well 1999 ended on a sour note in

901  
00:40:05,190 --> 00:40:02,860  
November of 1999 we lost our fourth gyro

902  
00:40:07,620 --> 00:40:05,200  
when a Hubble has six gyroscopes on it

903  
00:40:09,720 --> 00:40:07,630  
and it needs three gyroscopes to point

904  
00:40:11,910 --> 00:40:09,730  
you've got three directions XY and Z and

905  
00:40:13,170 --> 00:40:11,920  
you need three gyroscopes to work with

906  
00:40:16,800 --> 00:40:13,180  
each other to point the telescope

907  
00:40:19,290 --> 00:40:16,810  
accurately well one of our fourth

908  
00:40:22,260 --> 00:40:19,300  
gyroscopes failed in November of 1999

909  
00:40:25,680 --> 00:40:22,270  
Hubble was paid to safe mode and Hubble

910  
00:40:28,860 --> 00:40:25,690  
could not do any more observations until

911  
00:40:31,890 --> 00:40:28,870  
the astronauts went up to repair it how

912  
00:40:34,800 --> 00:40:31,900  
long was that going to take not long

913  
00:40:38,370 --> 00:40:34,810

NASA came to the rescue and in December

914

00:40:40,710 --> 00:40:38,380

1999 they put a Hubble servicing mission

915

00:40:43,590 --> 00:40:40,720

on to the manifest onto the shuttle

916

00:40:47,610 --> 00:40:43,600

manifest very quickly servicing mission

917

00:40:49,260 --> 00:40:47,620

3a now it's called 3a because we had a

918

00:40:51,120 --> 00:40:49,270

much larger servicing mission plan

919

00:40:53,820 --> 00:40:51,130

servicing full servicing mission three

920

00:40:56,220 --> 00:40:53,830

but because Hubble needed Hardware

921

00:40:58,760 --> 00:40:56,230

repairs they took the hardware repairs

922

00:41:00,510 --> 00:40:58,770

only and pushed it up in the schedule

923

00:41:03,000 --> 00:41:00,520

got up to Hubble

924

00:41:06,210 --> 00:41:03,010

almost immediately did the hardware

925

00:41:08,100 --> 00:41:06,220

repairs replace the gyroscopes you know

926

00:41:11,370 --> 00:41:08,110

topped off the fluids wash the

927

00:41:13,950 --> 00:41:11,380

windshield replace the magnet and the

928

00:41:16,670 --> 00:41:13,960

the recorders put on outer blanket

929

00:41:19,110 --> 00:41:16,680

layers insulation stuff like that okay

930

00:41:22,020 --> 00:41:19,120

didn't add any new capability to Hubble

931

00:41:24,660 --> 00:41:22,030

but repaired it and got it back into

932

00:41:26,610 --> 00:41:24,670

working order now of course when you

933

00:41:28,770 --> 00:41:26,620

have a successful servicing mission you

934

00:41:31,320 --> 00:41:28,780

have to announce it with with some

935

00:41:33,960 --> 00:41:31,330

beautiful images and in 2000 we

936

00:41:36,450 --> 00:41:33,970

announced it with this this was one of

937

00:41:40,650 --> 00:41:36,460

the images we use to announce it this is

938

00:41:42,850 --> 00:41:40,660

the galaxy cluster Abell 22-18 this is a

939

00:41:46,360 --> 00:41:42,860

galaxy cluster with thousands

940

00:41:48,160 --> 00:41:46,370

galaxies and the mass concentration in

941

00:41:51,910 --> 00:41:48,170

this globular cluster in this galaxy

942

00:41:55,390 --> 00:41:51,920

cluster is so great that it actually

943

00:41:57,490 --> 00:41:55,400

warps space now general relativity for

944

00:41:58,690 --> 00:41:57,500

those of you who come often there's a

945

00:42:04,230 --> 00:41:58,700

three word summary of general relativity

946

00:42:07,810 --> 00:42:04,240

anybody remember it mass warps space

947

00:42:09,970 --> 00:42:07,820

everybody say it with me mass warps

948

00:42:12,220 --> 00:42:09,980

space that's all you need to know about

949

00:42:16,030 --> 00:42:12,230

general relativity alright and there's

950

00:42:19,570 --> 00:42:16,040

so much mass in this galaxy cluster that

951  
00:42:22,000 --> 00:42:19,580  
the space has become warped and these

952  
00:42:24,820 --> 00:42:22,010  
are key streaky things that you see

953  
00:42:27,820 --> 00:42:24,830  
around this galaxy cluster are images of

954  
00:42:30,070 --> 00:42:27,830  
galaxies behind the cluster whose light

955  
00:42:32,980 --> 00:42:30,080  
has come through this warped space and

956  
00:42:34,900 --> 00:42:32,990  
becomes stretched out while passing

957  
00:42:37,480 --> 00:42:34,910  
through that warp space they're

958  
00:42:40,510 --> 00:42:37,490  
normal-looking galaxies but the images

959  
00:42:44,680 --> 00:42:40,520  
have become distorted by passing through

960  
00:42:49,390 --> 00:42:44,690  
distorted space how cool is that

961  
00:42:51,910 --> 00:42:49,400  
and you will note how thin and detailed

962  
00:42:54,310 --> 00:42:51,920  
you have to look in order to see these

963  
00:42:55,510 --> 00:42:54,320

these gravitational lenses these

964

00:42:59,790 --> 00:42:55,520

gravitationally lensed

965

00:43:02,440 --> 00:42:59,800

arcs and Hubble's resolution has enabled

966

00:43:05,710 --> 00:43:02,450

greater studies of gravitational lensing

967

00:43:08,380 --> 00:43:05,720

than was ever possible before seeing

968

00:43:11,470 --> 00:43:08,390

that amazing detail these fine detailed

969

00:43:14,200 --> 00:43:11,480

structures possible with Hubble and

970

00:43:17,110 --> 00:43:14,210

gravitational lensing it has really

971

00:43:21,100 --> 00:43:17,120

greatly put forward on the field of that

972

00:43:24,970 --> 00:43:21,110

field 2001 we returned to the solar

973

00:43:28,360 --> 00:43:24,980

system and Mars makes periodic

974

00:43:30,100 --> 00:43:28,370

approaches by earth ok earth is orbiting

975

00:43:32,440 --> 00:43:30,110

around a little faster than Mars Mars

976  
00:43:35,140 --> 00:43:32,450  
takes a little bit longer every two two

977  
00:43:36,880 --> 00:43:35,150  
and a half years they come to what's

978  
00:43:40,330 --> 00:43:36,890  
called conjunction Earth and Mars are at

979  
00:43:43,750 --> 00:43:40,340  
their closest approach ok Hubble always

980  
00:43:46,420 --> 00:43:43,760  
takes pictures of Mars why because the

981  
00:43:48,580 --> 00:43:46,430  
public loves the solar system alright

982  
00:43:49,570 --> 00:43:48,590  
you know cosmology is great those

983  
00:43:52,120 --> 00:43:49,580  
gravitational lensing things are

984  
00:43:53,980 --> 00:43:52,130  
fantastic but you know what the public

985  
00:43:56,259 --> 00:43:53,990  
responds to a solar system press release

986  
00:43:58,659 --> 00:43:56,269  
more than anything else

987  
00:44:00,249 --> 00:43:58,669  
also it's a really good time to study

988  
00:44:02,559 --> 00:44:00,259

Mars and we've got the best resolution

989

00:44:04,659 --> 00:44:02,569

that you can say you can have from Earth

990

00:44:05,979 --> 00:44:04,669

now of course the resolution is nothing

991

00:44:08,229 --> 00:44:05,989

compared to the spacecraft that are

992

00:44:10,749 --> 00:44:08,239

there at Mars we can't compete with that

993

00:44:13,089 --> 00:44:10,759

but you know we can do we can do some

994

00:44:16,659 --> 00:44:13,099

things one of the things we can do which

995

00:44:19,659 --> 00:44:16,669

we can monitor it long term see in June

996

00:44:22,809 --> 00:44:19,669

of 2001 here's the picture of Mars and

997

00:44:25,349 --> 00:44:22,819

you see that down that's the helis basin

998

00:44:28,479 --> 00:44:25,359

down there and there was a dust storm

999

00:44:30,519 --> 00:44:28,489

brewing in the Hellas Basin okay a giant

1000

00:44:33,159 --> 00:44:30,529

impact crater on Mars got a dust storm

1001  
00:44:34,419 --> 00:44:33,169  
brewing and so we watched it and we

1002  
00:44:39,209 --> 00:44:34,429  
looked in September

1003  
00:44:42,069 --> 00:44:39,219  
oh no is the flaw in the mirror back no

1004  
00:44:45,629 --> 00:44:42,079  
the dust storm that was a localized

1005  
00:44:46,799 --> 00:44:45,639  
disturbance in June has gone global in

1006  
00:44:50,499 --> 00:44:46,809  
September

1007  
00:44:53,079 --> 00:44:50,509  
Mars's atmosphere is 1/100 the density

1008  
00:44:55,509 --> 00:44:53,089  
of Earth's atmosphere and localized

1009  
00:44:58,689 --> 00:44:55,519  
disturbances can propagate to become

1010  
00:44:59,079 --> 00:44:58,699  
global phenomena that's what happens

1011  
00:45:02,289 --> 00:44:59,089  
here

1012  
00:45:06,059 --> 00:45:02,299  
Hubble gets to monitor the planets over

1013  
00:45:09,279 --> 00:45:06,069

the course of decades when you send a

1014

00:45:12,099 --> 00:45:09,289

spacecraft to a planet it's there for a

1015

00:45:13,719 --> 00:45:12,109

few years you know a Cassini is done

1016

00:45:15,609 --> 00:45:13,729

absolutely amazing being there as long

1017

00:45:17,649 --> 00:45:15,619

as it has been but Hubble is around

1018

00:45:18,939 --> 00:45:17,659

there for decades and sometimes I like

1019

00:45:21,789 --> 00:45:18,949

to refer to Hubble as the interplanetary

1020

00:45:24,069 --> 00:45:21,799

weather channel because it can monitor

1021

00:45:29,229 --> 00:45:24,079

what's going on in these planets from

1022

00:45:34,959 --> 00:45:29,239

here at earth over long-term 2001 also

1023

00:45:37,739 --> 00:45:34,969

saw an amazing amazing discovery this is

1024

00:45:42,999 --> 00:45:37,749

the Hubble Deep Field that was done in

1025

00:45:44,919 --> 00:45:43,009

1995 and in that ours this galaxies here

1026

00:45:48,879 --> 00:45:44,929

this the small suite of galaxies here

1027

00:45:53,589 --> 00:45:48,889

and in this galaxy here we observed a

1028

00:45:58,179 --> 00:45:53,599

supernova this galaxy is however 10

1029

00:46:01,599 --> 00:45:58,189

billion light years away making this the

1030

00:46:03,369 --> 00:46:01,609

most distant supernovae ever observed

1031

00:46:05,469 --> 00:46:03,379

now what you're seeing the lower

1032

00:46:08,199 --> 00:46:05,479

right-hand panel is basically two images

1033

00:46:09,430 --> 00:46:08,209

of this of these galaxies subtracted to

1034

00:46:11,740 --> 00:46:09,440

show you the light remain

1035

00:46:16,180 --> 00:46:11,750

that extra light that came from that

1036

00:46:21,309 --> 00:46:16,190

supernova now what's really cool about

1037

00:46:24,880 --> 00:46:21,319

this is that this supernova being so far

1038

00:46:27,339 --> 00:46:24,890

away being able to give us the distance

1039

00:46:29,410 --> 00:46:27,349

to that galaxy and compare it to its

1040

00:46:33,540 --> 00:46:29,420

redshift like we did with the Hubble

1041

00:46:37,059 --> 00:46:33,550

diagram was helped able to nail down a

1042

00:46:40,120 --> 00:46:37,069

cosmological model as you may be aware

1043

00:46:43,089 --> 00:46:40,130

in the late 1990s we had evidence that

1044

00:46:44,710 --> 00:46:43,099

the universe was accelerating the

1045

00:46:46,329 --> 00:46:44,720

expansion of the universe instead of

1046

00:46:50,410 --> 00:46:46,339

slowing down like we'd always thought it

1047

00:46:53,920 --> 00:46:50,420

would appear to be going faster but we

1048

00:46:55,750 --> 00:46:53,930

couldn't really tell unless we look way

1049

00:46:58,839 --> 00:46:55,760

way out in the universe our confidence

1050

00:47:00,940 --> 00:46:58,849

locally was very strong but unless we

1051

00:47:02,530 --> 00:47:00,950

looked way way out in the universe to

1052

00:47:07,390 --> 00:47:02,540

see back when the universe was slowing

1053

00:47:11,200 --> 00:47:07,400

down could we truly tell this galaxy

1054

00:47:13,690 --> 00:47:11,210

this supernova at a redshift of 1.7 the

1055

00:47:17,800 --> 00:47:13,700

most distant supernova ever observed was

1056

00:47:19,930 --> 00:47:17,810

a crucial point in getting in accepting

1057

00:47:23,349 --> 00:47:19,940

the accelerating universe and the

1058

00:47:27,880 --> 00:47:23,359

discovery of dark energy the kind of

1059

00:47:30,130 --> 00:47:27,890

thing only observable with Hubble 2002

1060

00:47:34,540 --> 00:47:30,140

we got the second half of servicing

1061

00:47:37,450 --> 00:47:34,550

mission 3 servicing mission 3b and again

1062

00:47:40,630 --> 00:47:37,460

the wonderful astronauts who went up and

1063

00:47:44,079 --> 00:47:40,640

serviced it now 2,000 smidgen 3b was

1064

00:47:47,020 --> 00:47:44,089

especially cool because we had for the

1065

00:47:49,180 --> 00:47:47,030

first time a major change of our primary

1066

00:47:51,720 --> 00:47:49,190

observing instrument we had been using

1067

00:47:54,010 --> 00:47:51,730

wide field planetary camera 2 since 1993

1068

00:47:56,800 --> 00:47:54,020

which was installed and servicing

1069

00:47:58,120 --> 00:47:56,810

mission 1 and in this servicing mission

1070

00:48:01,630 --> 00:47:58,130

we installed the advanced camera for

1071

00:48:06,940 --> 00:48:01,640

surveys going from a 3 megapixel camera

1072

00:48:09,339 --> 00:48:06,950

to a 16 megapixel camera going from one

1073

00:48:11,880 --> 00:48:09,349

tenth of an arcsecond resolution to one

1074

00:48:15,099 --> 00:48:11,890

twentieth of mark second resolution so

1075

00:48:19,230 --> 00:48:15,109

slightly larger field of view higher

1076

00:48:21,910 --> 00:48:19,240

resolution more pixels really exciting

1077

00:48:22,900 --> 00:48:21,920

we also during this mission I'll have to

1078

00:48:27,640 --> 00:48:22,910

say there

1079

00:48:29,230 --> 00:48:27,650

a power unit repair and I have to say

1080

00:48:31,450 --> 00:48:29,240

that one of the most dramatic lines I've

1081

00:48:33,069 --> 00:48:31,460

heard a NASA you know the the NASA guys

1082

00:48:34,750 --> 00:48:33,079

who are who are narrating these things

1083

00:48:38,529 --> 00:48:34,760

and they're very calm and very

1084

00:48:40,059 --> 00:48:38,539

professional he said something like you

1085

00:48:41,680 --> 00:48:40,069

know that when they disconnected the

1086

00:48:44,170 --> 00:48:41,690

power unit in order to do the repair

1087

00:48:49,890 --> 00:48:44,180

he said for the first time Hubble is

1088

00:48:53,770 --> 00:48:52,180

fortunately Hubble did recover from

1089

00:48:57,190 --> 00:48:53,780

open-heart surgery uh-huh

1090

00:48:59,079 --> 00:48:57,200

to go on and do amazing things with our

1091

00:49:01,420 --> 00:48:59,089

early release observations we included

1092

00:49:03,819 --> 00:49:01,430

this image of the mice galaxies which

1093

00:49:05,950 --> 00:49:03,829

looks a bit like the antennae but it's

1094

00:49:07,450 --> 00:49:05,960

now at Hubble resolution that antenna

1095

00:49:09,849 --> 00:49:07,460

image I showed you was from the ground

1096

00:49:12,400 --> 00:49:09,859

here you get to see all the detail as

1097

00:49:15,970 --> 00:49:12,410

well as those big long tidal tails and

1098

00:49:18,240 --> 00:49:15,980

the mice were part of our press release

1099

00:49:20,470 --> 00:49:18,250

to say Hubble is back and working

1100

00:49:23,339 --> 00:49:20,480

perhaps the most successful press

1101  
00:49:29,049 --> 00:49:23,349  
release we've ever done because we got

1102  
00:49:32,019 --> 00:49:29,059  
one two three four Hubble images on the

1103  
00:49:37,289 --> 00:49:32,029  
front page of the New York Times in full

1104  
00:49:40,269 --> 00:49:37,299  
color above the fold a grand slam of

1105  
00:49:43,269 --> 00:49:40,279  
public outreach if ever there was one

1106  
00:49:44,109 --> 00:49:43,279  
I don't know how we could possibly do

1107  
00:49:47,380 --> 00:49:44,119  
any better than that

1108  
00:49:49,260 --> 00:49:47,390  
so but we have tried for the past 13

1109  
00:49:51,430 --> 00:49:49,270  
years all right

1110  
00:49:54,460 --> 00:49:51,440  
2003 that advanced camera for surveys

1111  
00:49:57,130 --> 00:49:54,470  
puts it 16 megapixels to use and we

1112  
00:50:00,519 --> 00:49:57,140  
start doing mosaics this is a mosaic of

1113  
00:50:03,279 --> 00:50:00,529

72 million pixels of the sombrero galaxy

1114

00:50:06,010 --> 00:50:03,289

and it's a gorgeous galaxy with it's

1115

00:50:08,799 --> 00:50:06,020

amazing dust disk and the big halo of

1116

00:50:11,109 --> 00:50:08,809

stars but also you'll find that the

1117

00:50:14,140 --> 00:50:11,119

background galaxies all the details in

1118

00:50:15,970 --> 00:50:14,150

the background ACS is that much more

1119

00:50:17,769 --> 00:50:15,980

sensitive that it's not just the

1120

00:50:19,029 --> 00:50:17,779

foreground objects but we find ourselves

1121

00:50:21,789 --> 00:50:19,039

starting looking through the background

1122

00:50:24,690 --> 00:50:21,799

objects we're seeing amazing detail in

1123

00:50:28,779 --> 00:50:24,700

the background of all our images as well

1124

00:50:31,510 --> 00:50:28,789

too we also took a very deep look at a

1125

00:50:34,059 --> 00:50:31,520

nothing part near the Andromeda galaxy

1126

00:50:35,740 --> 00:50:34,069

so this is the region that we studied

1127

00:50:38,320 --> 00:50:35,750

well away from the center of the

1128

00:50:40,360 --> 00:50:38,330

a galaxy in the halo of the andromeda

1129

00:50:44,290 --> 00:50:40,370

galaxy we did what we call the stellar

1130

00:50:47,200 --> 00:50:44,300

deep field and this is an image in one

1131

00:50:50,280 --> 00:50:47,210

at which almost all the stars you see

1132

00:50:53,260 --> 00:50:50,290

are not in our galaxy

1133

00:50:57,190 --> 00:50:53,270

almost all the stars you see are in the

1134

00:50:59,530 --> 00:50:57,200

Andromeda galaxy this is an amazingly

1135

00:51:03,100 --> 00:50:59,540

deep image to study the stellar

1136

00:51:05,470 --> 00:51:03,110

populations within the Andromeda galaxy

1137

00:51:07,570 --> 00:51:05,480

for example okay by the way these also

1138

00:51:08,800 --> 00:51:07,580

are background galaxies we can't get rid

1139

00:51:11,170 --> 00:51:08,810

of them okay they're gonna be in the

1140

00:51:14,100 --> 00:51:11,180

background at all times but see this guy

1141

00:51:17,710 --> 00:51:14,110

right here that is a globular cluster

1142

00:51:20,440 --> 00:51:17,720

not in our galaxy but in the end dromeda

1143

00:51:23,350 --> 00:51:20,450

galaxy and for comparison I give you a

1144

00:51:25,690 --> 00:51:23,360

globular cluster in our own galaxy also

1145

00:51:29,080 --> 00:51:25,700

taken with Hubble Messier 80 in the

1146

00:51:31,530 --> 00:51:29,090

Milky Way and I guess what is it g1 or

1147

00:51:33,640 --> 00:51:31,540

something like that in Andromeda

1148

00:51:36,310 --> 00:51:33,650

absolutely amazing that we can get this

1149

00:51:41,190 --> 00:51:36,320

detail from a galaxy two-and-a-half

1150

00:51:45,430 --> 00:51:41,200

million light-years away unfortunately

1151

00:51:47,200 --> 00:51:45,440

this is a shot of the astronauts at the

1152

00:51:49,290 --> 00:51:47,210

landing of the space shuttle Columbia

1153

00:51:51,280 --> 00:51:49,300

after servicing mission three and

1154

00:51:53,260 --> 00:51:51,290

unfortunately this was the last

1155

00:51:55,960 --> 00:51:53,270

successful mission of the space shuttle

1156

00:51:58,300 --> 00:51:55,970

Columbia on its next mission it

1157

00:52:01,780 --> 00:51:58,310

disintegrated as it was coming in over

1158

00:52:04,750 --> 00:52:01,790

Texas and this gentleman right here Sean

1159

00:52:10,060 --> 00:52:04,760

O'Keefe was the then NASA Administrator

1160

00:52:12,190 --> 00:52:10,070

and in January of 2004 he decided that

1161

00:52:15,340 --> 00:52:12,200

it was too dangerous to go back to

1162

00:52:17,740 --> 00:52:15,350

Hubble that there was no safe haven for

1163

00:52:18,940 --> 00:52:17,750

the astronauts if they were going to the

1164

00:52:20,470 --> 00:52:18,950

space station

1165

00:52:22,240 --> 00:52:20,480

well the astronauts could hang out on

1166

00:52:25,630 --> 00:52:22,250

the space station if there was a problem

1167

00:52:28,210 --> 00:52:25,640

with the shuttle until a rescue mission

1168

00:52:28,960 --> 00:52:28,220

could be sent up but Hubble there was no

1169

00:52:32,050 --> 00:52:28,970

safe haven

1170

00:52:34,330 --> 00:52:32,060

so in January 2004 he announced the

1171

00:52:36,730 --> 00:52:34,340

cancellation of our last servicing

1172

00:52:41,880 --> 00:52:36,740

mission servicing mission for would be

1173

00:52:43,800 --> 00:52:41,890

no more I cannot describe the

1174

00:52:47,940 --> 00:52:43,810

I don't want to say depression but they

1175

00:52:50,340 --> 00:52:47,950

just the general around this building at

1176  
00:52:51,930 --> 00:52:50,350  
the time all right we'd been through so

1177  
00:52:53,760 --> 00:52:51,940  
much in getting and Hubble has tries

1178  
00:52:58,020 --> 00:52:53,770  
triumph but to not have that last

1179  
00:52:59,460 --> 00:52:58,030  
servicing mission well that was a that

1180  
00:53:02,400 --> 00:52:59,470  
was quite a blow we've already started

1181  
00:53:04,080 --> 00:53:02,410  
building the instruments for it okay but

1182  
00:53:06,540 --> 00:53:04,090  
that's not that doesn't mean that the

1183  
00:53:09,980 --> 00:53:06,550  
science stops so this is an image

1184  
00:53:14,430 --> 00:53:09,990  
released in 1994 looking at supernova

1185  
00:53:15,960 --> 00:53:14,440  
1987a now 87a is the closest supernova

1186  
00:53:17,700 --> 00:53:15,970  
since the invention of the telescope

1187  
00:53:19,740 --> 00:53:17,710  
it's actually in the Large Magellanic

1188  
00:53:21,840 --> 00:53:19,750

Cloud a satellite galaxy of the Milky

1189

00:53:23,670 --> 00:53:21,850

Way we've been very unlucky for the past

1190

00:53:28,490 --> 00:53:23,680

four hundred years we haven't had a good

1191

00:53:31,830 --> 00:53:28,500

supernova in our own galaxy but 87a

1192

00:53:34,110 --> 00:53:31,840

explode we observe the explosion in 1987

1193

00:53:36,030 --> 00:53:34,120

and this was the Hubble image in 1994

1194

00:53:38,520 --> 00:53:36,040

and you can see here is the star that

1195

00:53:42,260 --> 00:53:38,530

exploded here you can see there's a ring

1196

00:53:45,750 --> 00:53:42,270

here and these two amazing rings here

1197

00:53:49,080 --> 00:53:45,760

indicating that before the star exploded

1198

00:53:50,040 --> 00:53:49,090

there was some outbursts of material to

1199

00:53:53,400 --> 00:53:50,050

create these rings

1200

00:53:55,680 --> 00:53:53,410

whether it was jets illuminating this

1201  
00:53:57,780 --> 00:53:55,690  
you know rotating jets that would

1202  
00:54:00,210 --> 00:53:57,790  
illuminate the of these rings you have

1203  
00:54:01,950 --> 00:54:00,220  
this ring of material here well we've

1204  
00:54:04,290 --> 00:54:01,960  
been following it ever since

1205  
00:54:07,380 --> 00:54:04,300  
okay the closest supernova you betcha

1206  
00:54:09,450 --> 00:54:07,390  
Hubble's gonna follow it and in 2004 we

1207  
00:54:12,330 --> 00:54:09,460  
released this amazing series images of

1208  
00:54:14,160 --> 00:54:12,340  
that central ring so here is that ring

1209  
00:54:15,420 --> 00:54:14,170  
this bright spot here is just a star

1210  
00:54:18,420 --> 00:54:15,430  
that happens to be along the line of

1211  
00:54:22,740 --> 00:54:18,430  
sight so you can ignore that but as we

1212  
00:54:26,130 --> 00:54:22,750  
go through 95 96 to 98 you start to see

1213  
00:54:26,640 --> 00:54:26,140

other bright spots lighting up along the

1214

00:54:29,010 --> 00:54:26,650

ring

1215

00:54:32,850 --> 00:54:29,020

you'll also notice this central region

1216

00:54:35,520 --> 00:54:32,860

becoming blurrier and bigger until in

1217

00:54:38,700 --> 00:54:35,530

2003 you can see the entire ring is

1218

00:54:41,250 --> 00:54:38,710

basically lit up and this is the

1219

00:54:44,100 --> 00:54:41,260

supernova remnant what's happening here

1220

00:54:46,860 --> 00:54:44,110

is the star explodes and a shockwave

1221

00:54:47,400 --> 00:54:46,870

is sent out at tens of millions of miles

1222

00:54:50,550 --> 00:54:47,410

an hour

1223

00:54:52,550 --> 00:54:50,560

across interstellar space what you're

1224

00:54:55,990 --> 00:54:52,560

seeing here is that shockwave

1225

00:54:58,630 --> 00:54:56,000

encountering that inner ring and

1226  
00:55:01,900 --> 00:54:58,640  
heating up that inner rain we're seeing

1227  
00:55:03,760 --> 00:55:01,910  
in real-time the shockwave smashing into

1228  
00:55:07,900 --> 00:55:03,770  
this ring creating all these bright

1229  
00:55:11,770 --> 00:55:07,910  
regions plus we are seeing the gas of

1230  
00:55:14,110 --> 00:55:11,780  
the supernova remnant expand out in real

1231  
00:55:16,450 --> 00:55:14,120  
time we've been following this ever

1232  
00:55:19,510 --> 00:55:16,460  
since it's absolutely amazing not too

1233  
00:55:22,210 --> 00:55:19,520  
many things in astronomy happen in real

1234  
00:55:23,920 --> 00:55:22,220  
time and Hubble has been there to be

1235  
00:55:29,380 --> 00:55:23,930  
able to monitor the expansion of

1236  
00:55:30,820 --> 00:55:29,390  
supernova 87a now also in 1996 we did

1237  
00:55:35,770 --> 00:55:30,830  
the Hubble Deep Field I'd mentioned it

1238  
00:55:38,320 --> 00:55:35,780

previously this was quite a risky

1239

00:55:41,170 --> 00:55:38,330

observation basically the director at

1240

00:55:44,110 --> 00:55:41,180

the time put all his discretionary time

1241

00:55:45,880 --> 00:55:44,120

into one observation and it's an

1242

00:55:49,810 --> 00:55:45,890

observation that a lot of astronomers

1243

00:55:52,720 --> 00:55:49,820

said would totally fail because distant

1244

00:55:54,790 --> 00:55:52,730

galaxies if you believe some models were

1245

00:55:58,060 --> 00:55:54,800

predicted to be too small for even

1246

00:56:00,400 --> 00:55:58,070

Hubble to see that as you go further out

1247

00:56:03,370 --> 00:56:00,410

the galaxies smaller and smaller you're

1248

00:56:05,230 --> 00:56:03,380

not going to be able to see anything but

1249

00:56:07,540 --> 00:56:05,240

he put all his eggs in one basket and

1250

00:56:10,330 --> 00:56:07,550

produced this amazing image the Hubble

1251  
00:56:13,210 --> 00:56:10,340  
Deep Field showing that you really could

1252  
00:56:15,580 --> 00:56:13,220  
do deep universe observations with how

1253  
00:56:18,160 --> 00:56:15,590  
well that Hubble's resolution was good

1254  
00:56:20,050 --> 00:56:18,170  
enough well we got the advanced camera

1255  
00:56:22,240 --> 00:56:20,060  
for surveys the direct new director said

1256  
00:56:24,300 --> 00:56:22,250  
I got to repeat this with our new

1257  
00:56:28,240 --> 00:56:24,310  
instrument with twice the resolution and

1258  
00:56:30,400 --> 00:56:28,250  
many times the pixels and so in 2004 we

1259  
00:56:35,700 --> 00:56:30,410  
also came out with the Hubble Ultra Deep

1260  
00:56:38,440 --> 00:56:35,710  
Field okay and this is probably the most

1261  
00:56:41,230 --> 00:56:38,450  
scientifically productive image Hubble

1262  
00:56:44,650 --> 00:56:41,240  
has ever created all right it has

1263  
00:56:46,690 --> 00:56:44,660

approximately 10,000 galaxies all the

1264

00:56:49,540 --> 00:56:46,700

way stretched across space and time

1265

00:56:52,030 --> 00:56:49,550

looking way out into the universe from

1266

00:56:53,530 --> 00:56:52,040

our big nearby galaxies and when I say

1267

00:56:55,390 --> 00:56:53,540

nearby I know that that galaxy is about

1268

00:56:57,520 --> 00:56:55,400

two billion light-years away so that's

1269

00:56:59,860 --> 00:56:57,530

nearby in this image just a couple

1270

00:57:01,660 --> 00:56:59,870

billion light-years away is nearby all

1271

00:57:03,070 --> 00:57:01,670

the way down to I don't know if I can

1272

00:57:05,590 --> 00:57:03,080

pick out one of the red dots there's a

1273

00:57:07,150 --> 00:57:05,600

bunch of little red tiny red dots you

1274

00:57:08,580 --> 00:57:07,160

probably can't see it at this resolution

1275

00:57:12,270 --> 00:57:08,590

tiny time

1276

00:57:15,330 --> 00:57:12,280

red dot stretching out 10 billion

1277

00:57:17,520 --> 00:57:15,340

light-years across the universe a core

1278

00:57:21,540 --> 00:57:17,530

sample through the universe looking at

1279

00:57:25,560 --> 00:57:21,550

galaxies out in space but also back in

1280

00:57:28,950 --> 00:57:25,570

time because this galaxy being 2 billion

1281

00:57:32,100 --> 00:57:28,960

light years away the light has taken 2

1282

00:57:35,520 --> 00:57:32,110

billion years to cross the intervening

1283

00:57:41,430 --> 00:57:35,530

space so we're seeing this galaxy as it

1284

00:57:45,540 --> 00:57:41,440

was 2 billion years ago this image looks

1285

00:57:48,540 --> 00:57:45,550

out into space back into time and shows

1286

00:57:49,970 --> 00:57:48,550

us the history of galaxy development

1287

00:57:52,890 --> 00:57:49,980

across the universe

1288

00:57:54,570 --> 00:57:52,900

you know a history teacher can't look

1289

00:57:57,600 --> 00:57:54,580

out and see the battles of get Battle of

1290

00:58:00,390 --> 00:57:57,610

Gettysburg but we as astronomers can

1291

00:58:03,630 --> 00:58:00,400

look out and see what galaxies were like

1292

00:58:06,030 --> 00:58:03,640

billions of years ago to give us an

1293

00:58:09,890 --> 00:58:06,040

understanding of how galaxies developed

1294

00:58:17,250 --> 00:58:14,220

unfortunately in early 2005 the advanced

1295

00:58:20,010 --> 00:58:17,260

camera for surveys its warranty

1296

00:58:22,170 --> 00:58:20,020

obviously expired and it had an

1297

00:58:24,660 --> 00:58:22,180

electrical fault okay all of our

1298

00:58:26,880 --> 00:58:24,670

instruments on Hubble have redundant

1299

00:58:29,220 --> 00:58:26,890

electronics the one side of the

1300

00:58:31,230 --> 00:58:29,230

electronics had failed previously the

1301  
00:58:32,970 --> 00:58:31,240  
second side of the atronics failed our

1302  
00:58:35,250 --> 00:58:32,980  
main instrument the instrument that took

1303  
00:58:36,150 --> 00:58:35,260  
that Hubble Ultra Deep Field image was

1304  
00:58:39,170 --> 00:58:36,160  
now offline

1305  
00:58:42,420 --> 00:58:39,180  
here it is 2005 and what are we gonna do

1306  
00:58:44,820 --> 00:58:42,430  
we're gonna go back to the white oak I'm

1307  
00:58:48,030 --> 00:58:44,830  
sorry this isn't this is an ACS this is

1308  
00:58:49,890 --> 00:58:48,040  
this just failed in 2005 ACS will fail a

1309  
00:58:53,340 --> 00:58:49,900  
little a little later sorry about that I

1310  
00:58:55,680 --> 00:58:53,350  
blown it the surprise is gone okay um

1311  
00:58:58,380 --> 00:58:55,690  
the Space Telescope imaging spectrograph

1312  
00:58:59,940 --> 00:58:58,390  
failed first I'm sorry I should know

1313  
00:59:02,010 --> 00:58:59,950

because the the picture of the ACS

1314

00:59:04,170 --> 00:59:02,020

actually says ACS on it all right this

1315

00:59:06,240 --> 00:59:04,180

is not them trying to repair it this is

1316

00:59:09,240 --> 00:59:06,250

actually as they were building this dis

1317

00:59:10,500 --> 00:59:09,250

instrument okay not to get anybody think

1318

00:59:14,210 --> 00:59:10,510

that we actually could go up and do this

1319

00:59:17,940 --> 00:59:14,220

kind of repair so we're without still

1320

00:59:20,010 --> 00:59:17,950

2005 our 15th anniversary we released

1321

00:59:20,550 --> 00:59:20,020

this amazing image of the Whirlpool

1322

00:59:21,780 --> 00:59:20,560

Galaxy

1323

00:59:26,190 --> 00:59:21,790

also known as

1324

00:59:28,650 --> 00:59:26,200

see a 50 196 million pixels of visual

1325

00:59:30,330 --> 00:59:28,660

goodness here what I love about this

1326

00:59:33,120 --> 00:59:30,340

image is that you can see the

1327

00:59:35,310 --> 00:59:33,130

progression of star formation within a

1328

00:59:38,700 --> 00:59:35,320

galaxy you've got the dark dust lanes

1329

00:59:40,860 --> 00:59:38,710

that that identify the spiral arms that

1330

00:59:43,020 --> 00:59:40,870

trace the spiral arms outside of them

1331

00:59:45,240 --> 00:59:43,030

you've got all these pink regions these

1332

00:59:47,120 --> 00:59:45,250

are the star forming regions we're still

1333

00:59:50,550 --> 00:59:47,130

where that dense gas and the dust

1334

00:59:52,350 --> 00:59:50,560

collapses and creates new stars and then

1335

00:59:54,360 --> 00:59:52,360

outside of those pink regions you see

1336

00:59:57,870 --> 00:59:54,370

these wonderful blue star clusters the

1337

01:00:00,300 --> 00:59:57,880

newborn stars going from the dense gas

1338

01:00:02,070 --> 01:00:00,310

that collapses to the stars that form to

1339

01:00:06,600 --> 01:00:02,080

the star clusters that are revealed when

1340

01:00:09,090 --> 01:00:06,610

that star formation is done also in 2005

1341

01:00:13,920 --> 01:00:09,100

we got this amazing picture of the Crab

1342

01:00:15,990 --> 01:00:13,930

Nebula this is a supernova not 10 or 20

1343

01:00:18,240 --> 01:00:16,000

years after it had exploded but a

1344

01:00:20,910 --> 01:00:18,250

thousand years after it exploded this

1345

01:00:24,870 --> 01:00:20,920

supernova was observed by chinese

1346

01:00:27,480 --> 01:00:24,880

astronomers in 1054 I believe about a

1347

01:00:29,370 --> 01:00:27,490

thousand years ago and all that material

1348

01:00:31,710 --> 01:00:29,380

streaming across space you saw that

1349

01:00:34,350 --> 01:00:31,720

little nebulous starting to form in the

1350

01:00:37,050 --> 01:00:34,360

center of a supernova 87a this is what

1351

01:00:39,450 --> 01:00:37,060

it looks like a thousand years later for

1352

01:00:42,030 --> 01:00:39,460

the Crab Nebula if you want to take a

1353

01:00:44,660 --> 01:00:42,040

look at one that's 30,000 years old we

1354

01:00:48,090 --> 01:00:44,670

also got a picture of Cassiopeia A in

1355

01:00:50,640 --> 01:00:48,100

2006 an older supernova remnant that has

1356

01:00:53,250 --> 01:00:50,650

expanded across space for 30,000 years

1357

01:00:56,280 --> 01:00:53,260

leaving a beautiful bubble this bubble

1358

01:00:59,400 --> 01:00:56,290

like shell the star that exploded long

1359

01:01:02,760 --> 01:00:59,410

gone and seeing the shell of material

1360

01:01:05,130 --> 01:01:02,770

and this exemplifies the cosmic

1361

01:01:07,440 --> 01:01:05,140

recycling in our galaxy that the

1362

01:01:09,630 --> 01:01:07,450

elements form inside stars you fuse

1363

01:01:12,900 --> 01:01:09,640

hydrogen to helium helium to carbon

1364

01:01:14,580 --> 01:01:12,910

nitrogen oxygen and so on up the ladder

1365

01:01:16,140 --> 01:01:14,590

and then with these giant supernova

1366

01:01:22,020 --> 01:01:16,150

explosions those elements are blown

1367

01:01:25,080 --> 01:01:22,030

across space and recycled into into the

1368

01:01:27,780 --> 01:01:25,090

interstellar medium and in some pockets

1369

01:01:30,360 --> 01:01:27,790

of those interstellar medium stars will

1370

01:01:33,410 --> 01:01:30,370

form and around some of those stars

1371

01:01:35,670 --> 01:01:33,420

planets will form and the heavy elements

1372

01:01:42,150 --> 01:01:35,680

which can only four

1373

01:01:47,310 --> 01:01:42,160

inside these stars form to create all

1374

01:01:50,060 --> 01:01:47,320

the carbon in your the oxygen in your in

1375

01:01:52,920 --> 01:01:50,070

your lungs the calcium in your teeth

1376

01:01:55,650 --> 01:01:52,930

because of the carbon in our bones all

1377

01:01:58,560 --> 01:01:55,660

of those elements were forged in the

1378

01:02:02,280 --> 01:01:58,570

interiors of stars and blown across

1379

01:02:04,920 --> 01:02:02,290

space by these supernova remnants so

1380

01:02:10,050 --> 01:02:04,930

there's a great cosmic connection to

1381

01:02:12,330 --> 01:02:10,060

images like this 2006 also produced one

1382

01:02:14,460 --> 01:02:12,340

of my favorite images simply because we

1383

01:02:16,620 --> 01:02:14,470

got to work with it on the IMAX film of

1384

01:02:19,640 --> 01:02:16,630

the Orion Nebula now I showed you the

1385

01:02:23,070 --> 01:02:19,650

1995 version of Orion that was a

1386

01:02:26,880 --> 01:02:23,080

relatively small region in here this one

1387

01:02:28,620 --> 01:02:26,890

is much larger actually it was so large

1388

01:02:31,500 --> 01:02:28,630

that we couldn't with the computers of

1389

01:02:35,550 --> 01:02:31,510

the time process the entire image you'll

1390

01:02:38,910 --> 01:02:35,560

find on our website is about a 320

1391

01:02:40,200 --> 01:02:38,920

million pixel image the full one had we

1392

01:02:41,940 --> 01:02:40,210

been able to process it at full

1393

01:02:44,160 --> 01:02:41,950

resolution and release it would have

1394

01:02:46,260 --> 01:02:44,170

been about a billion pixels which for

1395

01:02:48,990 --> 01:02:46,270

the computers at the time was not I'm

1396

01:02:51,570 --> 01:02:49,000

not feasible but again even more detail

1397

01:02:54,300 --> 01:02:51,580

of the amazing star formation going on

1398

01:03:00,210 --> 01:02:54,310

inside this nearest of the large star

1399

01:03:03,390 --> 01:03:00,220

foreign regions to us good news 2006

1400

01:03:06,000 --> 01:03:03,400

also saw a we had a new NASA

1401

01:03:09,830 --> 01:03:06,010

Administrator Michael Griffin he came on

1402

01:03:11,900 --> 01:03:09,840

if a couple years before this and he

1403

01:03:14,340 --> 01:03:11,910

commissioned a study to look at

1404

01:03:16,770 --> 01:03:14,350

servicing mission a possibility of a

1405

01:03:19,470 --> 01:03:16,780

servicing mission for and in the middle

1406

01:03:23,520 --> 01:03:19,480

of the year he added a servicing mission

1407

01:03:25,980 --> 01:03:23,530

for back onto the manifest but in order

1408

01:03:27,600 --> 01:03:25,990

to protect the astronauts it was decreed

1409

01:03:29,220 --> 01:03:27,610

that he could not do his Hubble

1410

01:03:33,180 --> 01:03:29,230

servicing mission unless there was a

1411

01:03:36,390 --> 01:03:33,190

second shuttle on the launch pad ready

1412

01:03:38,970 --> 01:03:36,400

to go in case a rescue mission was

1413

01:03:40,830 --> 01:03:38,980

needed so that was our solution if

1414

01:03:43,140 --> 01:03:40,840

you're gonna go to Hubble you need two

1415

01:03:45,480 --> 01:03:43,150

shuttles on the launch pad at the same

1416

01:03:47,910 --> 01:03:45,490

time of course that it happened before

1417

01:03:49,490 --> 01:03:47,920

it Hubble's launch so we're gonna do it

1418

01:03:52,289 --> 01:03:49,500

again

1419

01:03:54,349 --> 01:03:52,299

as we might say the mood around this

1420

01:03:57,990 --> 01:03:54,359

building really lightened after that

1421

01:04:00,569 --> 01:03:58,000

much jubilation after that however this

1422

01:04:03,589 --> 01:04:00,579

is when ACS now you can see it is ACS

1423

01:04:07,529 --> 01:04:03,599

because there it is um ACS failed

1424

01:04:09,029 --> 01:04:07,539

alright so again without the Space

1425

01:04:11,039 --> 01:04:09,039

Telescope imaging spectrograph or

1426  
01:04:12,779 --> 01:04:11,049  
without the advanced camera surveys two

1427  
01:04:15,089 --> 01:04:12,789  
of our really important instruments are

1428  
01:04:16,829 --> 01:04:15,099  
no longer working we really really want

1429  
01:04:19,490 --> 01:04:16,839  
that servicing mission to come as soon

1430  
01:04:22,500 --> 01:04:19,500  
as possible but it was scheduled for

1431  
01:04:25,829 --> 01:04:22,510  
2008 so we got lots of science to go

1432  
01:04:30,240 --> 01:04:25,839  
through 2007 this is an artist's

1433  
01:04:34,109 --> 01:04:30,250  
illustration of a of a planet around a

1434  
01:04:36,690 --> 01:04:34,119  
star and in a jupiter-sized planet in a

1435  
01:04:40,710 --> 01:04:36,700  
mercury sized orbit we call them hot

1436  
01:04:43,109 --> 01:04:40,720  
Jupiters but this one actually passes in

1437  
01:04:47,700 --> 01:04:43,119  
front of it of the star from our point

1438  
01:04:49,589 --> 01:04:47,710

of view which makes it really cool well

1439

01:04:52,529 --> 01:04:49,599

actually it's really hot but really cool

1440

01:04:55,440 --> 01:04:52,539

to study because you can see as that

1441

01:04:57,240 --> 01:04:55,450

planet passes in front of its star some

1442

01:05:00,180 --> 01:04:57,250

of the light of the star will go through

1443

01:05:03,269 --> 01:05:00,190

the atmosphere of this star and this

1444

01:05:06,059 --> 01:05:03,279

star is so cool this planet is so close

1445

01:05:08,910 --> 01:05:06,069

to its star that it's atmospheres

1446

01:05:11,009 --> 01:05:08,920

actually heated up and extended so if

1447

01:05:13,559 --> 01:05:11,019

you take a picture or a spectrograph

1448

01:05:15,839 --> 01:05:13,569

when the planet is in front of the star

1449

01:05:18,230 --> 01:05:15,849

and take another when the planet is not

1450

01:05:22,859 --> 01:05:18,240

in front of the star subtract the two

1451  
01:05:25,920 --> 01:05:22,869  
what do you get you get to measure the

1452  
01:05:28,589 --> 01:05:25,930  
atmosphere of a planet around another

1453  
01:05:31,039 --> 01:05:28,599  
star now you can't actually see this

1454  
01:05:33,480 --> 01:05:31,049  
planet but you can measure its

1455  
01:05:35,130 --> 01:05:33,490  
atmosphere and this atmosphere is

1456  
01:05:37,799 --> 01:05:35,140  
extended and we're able to measure

1457  
01:05:39,990 --> 01:05:37,809  
hydrogen and silicon and nitrogen a

1458  
01:05:43,620 --> 01:05:40,000  
couple other elements in the atmosphere

1459  
01:05:47,579 --> 01:05:43,630  
of another planet and I have to say this

1460  
01:05:50,339 --> 01:05:47,589  
is one of the Hubble discoveries that we

1461  
01:05:52,829 --> 01:05:50,349  
hadn't even dreamed of when Hubble was

1462  
01:05:56,009 --> 01:05:52,839  
launched one of the great things about

1463  
01:05:58,440 --> 01:05:56,019

science is that if you design a general

1464

01:06:00,920 --> 01:05:58,450

purpose instrument you could actually do

1465

01:06:02,550 --> 01:06:00,930

science you didn't even think possible

1466

01:06:07,230 --> 01:06:02,560

when

1467

01:06:12,330 --> 01:06:07,240

and this is one of the one of the major

1468

01:06:15,710 --> 01:06:12,340

ones also in 2007 we got well this was

1469

01:06:19,290 --> 01:06:15,720

our this was until last Monday the

1470

01:06:22,560 --> 01:06:19,300

largest mosaic Hubble has ever done this

1471

01:06:24,810 --> 01:06:22,570

is of the Carina Nebula another star

1472

01:06:26,670 --> 01:06:24,820

forming region that ATAC our image that

1473

01:06:29,460 --> 01:06:26,680

I showed you is this small thing right

1474

01:06:31,590 --> 01:06:29,470

here down inside there you can see it's

1475

01:06:33,360 --> 01:06:31,600

just part of a much larger star forming

1476  
01:06:36,150 --> 01:06:33,370  
region you can see there's an amazing

1477  
01:06:37,800 --> 01:06:36,160  
bubble a cavity drawn by these bright

1478  
01:06:40,500 --> 01:06:37,810  
stars and they're hot winds and

1479  
01:06:42,540 --> 01:06:40,510  
everything and we've got this the

1480  
01:06:44,880 --> 01:06:42,550  
pillars here and pillars down here and

1481  
01:06:49,830 --> 01:06:44,890  
all sorts of cool stuff going on in here

1482  
01:06:52,620 --> 01:06:49,840  
this 350 300 400 million pixel image

1483  
01:06:57,140 --> 01:06:52,630  
shows off the incredible detail Hubble

1484  
01:07:00,000 --> 01:06:57,150  
can see in these star forming regions

1485  
01:07:02,280 --> 01:07:00,010  
2008 well let's get to Jupiter because

1486  
01:07:03,660 --> 01:07:02,290  
we talked about Jupiter's storms we

1487  
01:07:05,400 --> 01:07:03,670  
talked about Saturn's storms and how

1488  
01:07:07,950 --> 01:07:05,410

Jupiter is used to having storm well we

1489

01:07:09,120 --> 01:07:07,960  
are used to one major storm always being

1490

01:07:12,060 --> 01:07:09,130  
there on Jupiter

1491

01:07:13,740 --> 01:07:12,070  
and that is the great red spot we have

1492

01:07:15,900 --> 01:07:13,750  
seen it ever since we started looking at

1493

01:07:19,650 --> 01:07:15,910  
we have continuous observations back to

1494

01:07:22,950 --> 01:07:19,660  
the 1800s we may even have seen it back

1495

01:07:26,040 --> 01:07:22,960  
in 1670 when Giovanni Cassini he's got a

1496

01:07:27,930 --> 01:07:26,050  
wonderful drawing in a 1670 scientific

1497

01:07:30,780 --> 01:07:27,940  
journal and I swear it looks like the

1498

01:07:32,090 --> 01:07:30,790  
Great Red Spot so it's always been there

1499

01:07:35,750 --> 01:07:32,100  
all right

1500

01:07:38,640 --> 01:07:35,760  
in 2003 several of these white ovals

1501  
01:07:42,270 --> 01:07:38,650  
merged to form what we called Red Spot

1502  
01:07:45,360 --> 01:07:42,280  
jr. the first time we'd ever seen the

1503  
01:07:49,890 --> 01:07:45,370  
formation of a Red Spot and in early

1504  
01:07:52,440 --> 01:07:49,900  
2008 another red spot appeared this was

1505  
01:07:56,100 --> 01:07:52,450  
the Great Red Spot red jr. so we call

1506  
01:07:58,290 --> 01:07:56,110  
that baby red spot now red jr. is on a

1507  
01:08:00,450 --> 01:07:58,300  
different latitude and has passed by the

1508  
01:08:02,390 --> 01:08:00,460  
great red spots several times and

1509  
01:08:05,760 --> 01:08:02,400  
appears to be a long live storm

1510  
01:08:08,700 --> 01:08:05,770  
however red the baby red spot is on the

1511  
01:08:11,520 --> 01:08:08,710  
same latitude as Jupiter and so we

1512  
01:08:13,950 --> 01:08:11,530  
watched over the summer of 2008 as it

1513  
01:08:15,010 --> 01:08:13,960

got caught in the vortices and was

1514

01:08:16,420 --> 01:08:15,020

dissipated

1515

01:08:20,260 --> 01:08:16,430

for the first time we saw the

1516

01:08:21,970 --> 01:08:20,270

destruction of a red spot and we also

1517

01:08:24,670 --> 01:08:21,980

learned how vicious the great red spot

1518

01:08:31,539 --> 01:08:24,680

is it's such a vicious storm it'll even

1519

01:08:35,470 --> 01:08:31,549

eat its own young 2008 also saw this

1520

01:08:37,180 --> 01:08:35,480

wonderful image this is a forum a lot or

1521

01:08:39,190 --> 01:08:37,190

actually it's everything but the star

1522

01:08:40,990 --> 01:08:39,200

forum a lot again the light of fo Milan

1523

01:08:42,519 --> 01:08:41,000

has been blocked and it's got a dust

1524

01:08:43,829 --> 01:08:42,529

ring around it looks similar to some of

1525

01:08:46,570 --> 01:08:43,839

the show images I've shown you before

1526

01:08:49,570 --> 01:08:46,580

but the special thing about this dust

1527

01:08:52,720 --> 01:08:49,580

ring is that it's off-center FOMA hot is

1528

01:08:54,579 --> 01:08:52,730

not at the center which indicates that

1529

01:08:57,640 --> 01:08:54,589

there's some gravitational influence

1530

01:08:59,950 --> 01:08:57,650

pulling it off center so it was searched

1531

01:09:05,349 --> 01:08:59,960

to see if we could find a planet in it

1532

01:09:09,640 --> 01:09:05,359

and in 2008 we saw the first image ever

1533

01:09:14,110 --> 01:09:09,650

of a planet around another star right

1534

01:09:15,849 --> 01:09:14,120

there a beautiful red dot but it's an

1535

01:09:18,910 --> 01:09:15,859

amazing red dot when you think of it

1536

01:09:21,280 --> 01:09:18,920

because this is not a planet I'm telling

1537

01:09:23,860 --> 01:09:21,290

you is there because if it's gravity or

1538

01:09:27,010 --> 01:09:23,870

because I detect it blocking some light

1539

01:09:30,970 --> 01:09:27,020

it's not an indirect detection this is

1540

01:09:32,769 --> 01:09:30,980

the first direct detection on a planet

1541

01:09:34,780 --> 01:09:32,779

around another star now this is the one

1542

01:09:37,960 --> 01:09:34,790

in visible light using visible light in

1543

01:09:40,360 --> 01:09:37,970

the exact same issue of the exact same

1544

01:09:43,559 --> 01:09:40,370

scientific journal another group

1545

01:09:48,160 --> 01:09:43,569

released images in infrared light so

1546

01:09:50,769 --> 01:09:48,170

starting in 2008 we finally have direct

1547

01:09:54,820 --> 01:09:50,779

detection seeing planets around other

1548

01:09:57,070 --> 01:09:54,830

stars and you think about how we've come

1549

01:09:59,110 --> 01:09:57,080

far we come over the first 18 years of

1550

01:10:00,340 --> 01:09:59,120

Hubble going from not even knowing there

1551

01:10:03,460 --> 01:10:00,350

were planets around other stars

1552

01:10:05,590 --> 01:10:03,470

to finally seeing them you can see what

1553

01:10:10,630 --> 01:10:05,600

a spectrum of science this mission has

1554

01:10:12,880 --> 01:10:10,640

covered 2008 was that finally we get

1555

01:10:15,310 --> 01:10:12,890

around to servicing mission 4 and a

1556

01:10:17,260 --> 01:10:15,320

quote from a higher high ranking person

1557

01:10:20,200 --> 01:10:17,270

at NASA says this final mission will be

1558

01:10:22,900 --> 01:10:20,210

without doubt the most complicated and

1559

01:10:27,070 --> 01:10:22,910

challenging that nASA has ever mounted

1560

01:10:28,900 --> 01:10:27,080

so here we are in September of 2008 we

1561

01:10:31,390 --> 01:10:28,910

have the Space Shuttle on the line

1562

01:10:32,740 --> 01:10:31,400

we have the second space shuttle on the

1563

01:10:34,990 --> 01:10:32,750

launch pad there's a beautiful rainbow

1564

01:10:38,200 --> 01:10:35,000

up here that I had to crop off to get

1565

01:10:43,180 --> 01:10:38,210

the image in amazing shot all right

1566

01:10:44,560 --> 01:10:43,190

we're ready to go and then a science

1567

01:10:48,340 --> 01:10:44,570

instrument control and data handling

1568

01:10:50,200 --> 01:10:48,350

unit failed now this was just the a side

1569

01:10:52,570 --> 01:10:50,210

of the electronics of the si si and EH

1570

01:10:55,120 --> 01:10:52,580

and there was a B side so we immediately

1571

01:10:57,400 --> 01:10:55,130

switched to the B side but science

1572

01:10:59,740 --> 01:10:57,410

instrument control this is the hardware

1573

01:11:02,500 --> 01:10:59,750

that controls every science instrument

1574

01:11:03,970 --> 01:11:02,510

on Hubble data handling unit every bit

1575

01:11:07,210 --> 01:11:03,980

of data goes through this piece of

1576

01:11:09,580 --> 01:11:07,220

hardware so when it failed three weeks

1577

01:11:12,520 --> 01:11:09,590

before launch and even though it was a

1578

01:11:14,260 --> 01:11:12,530

repairable fail we didn't want to have

1579

01:11:17,710 --> 01:11:14,270

any single points of failure

1580

01:11:20,560 --> 01:11:17,720

so NASA delayed the mission while a

1581

01:11:23,650 --> 01:11:20,570

ground spare that Goddard Space Flight

1582

01:11:25,570 --> 01:11:23,660

Center was made ready for space so that

1583

01:11:28,870 --> 01:11:25,580

mission that we've been waiting for was

1584

01:11:31,630 --> 01:11:28,880

delayed yet another six months until May

1585

01:11:35,170 --> 01:11:31,640

of 2009 when we finally got the launch

1586

01:11:37,600 --> 01:11:35,180

of servicing mission 4 now servicing

1587

01:11:39,790 --> 01:11:37,610

mission 4 tackled an enormous number of

1588

01:11:41,980 --> 01:11:39,800

tasks because it was the final mission

1589

01:11:44,020 --> 01:11:41,990

to Hubble and we knew it we were not

1590

01:11:46,840 --> 01:11:44,030

going to get another mission to Hubble

1591

01:11:50,410 --> 01:11:46,850

so we changed out the batteries we put

1592

01:11:52,660 --> 01:11:50,420

in new gyros we put a pulled out wide

1593

01:11:56,170 --> 01:11:52,670

field planetary camera 2 we put in Wide

1594

01:11:59,290 --> 01:11:56,180

Field Camera 3 we repaired ACS we

1595

01:12:02,200 --> 01:11:59,300

repaired this we put in new insulation

1596

01:12:04,960 --> 01:12:02,210

we did everything possible to leave

1597

01:12:08,260 --> 01:12:04,970

Hubble and as good a shape as paw as we

1598

01:12:09,430 --> 01:12:08,270

could and unbelievably the astronauts

1599

01:12:11,890 --> 01:12:09,440

accomplished it all

1600

01:12:13,240 --> 01:12:11,900

they went well past their space time the

1601  
01:12:15,700 --> 01:12:13,250  
time they're supposed to do for

1602  
01:12:18,910 --> 01:12:15,710  
spacewalks they accomplished everything

1603  
01:12:21,520 --> 01:12:18,920  
on the list all right and this is a

1604  
01:12:24,310 --> 01:12:21,530  
bittersweet shot because this is Hubble

1605  
01:12:27,640 --> 01:12:24,320  
repaired but this is also the last time

1606  
01:12:29,710 --> 01:12:27,650  
human eyes got to see Hubble because as

1607  
01:12:31,630 --> 01:12:29,720  
the astronauts were leaving this is one

1608  
01:12:35,470 --> 01:12:31,640  
of the last shots they got saying

1609  
01:12:38,050 --> 01:12:35,480  
goodbye to Hubble of course the science

1610  
01:12:40,240 --> 01:12:38,060  
comes out amazing the early-release

1611  
01:12:41,120 --> 01:12:40,250  
observations included the butterfly

1612  
01:12:44,840 --> 01:12:41,130  
nebula

1613  
01:12:46,879 --> 01:12:44,850

our press release said it looked like a

1614

01:12:48,709 --> 01:12:46,889

butterfly and the press ran with it

1615

01:12:53,930 --> 01:12:48,719

so now most people call it the butterfly

1616

01:12:56,780 --> 01:12:53,940

nebula this is a dying star a planetary

1617

01:12:57,950 --> 01:12:56,790

nebula as they call it not because it

1618

01:12:59,360 --> 01:12:57,960

has anything to do with planets but

1619

01:13:02,149 --> 01:12:59,370

that's just what they were called

1620

01:13:05,060 --> 01:13:02,159

and the material streaming away from the

1621

01:13:07,610 --> 01:13:05,070

star is constrained by a disc around

1622

01:13:10,070 --> 01:13:07,620

here so it goes off in these hourglass

1623

01:13:12,830 --> 01:13:10,080

shapes here creating an amazing and

1624

01:13:14,570 --> 01:13:12,840

beautiful wheel nebula we also released

1625

01:13:17,090 --> 01:13:14,580

this image of the core of the globular

1626  
01:13:19,430 --> 01:13:17,100  
cluster omega centauri i talked to you

1627  
01:13:22,790 --> 01:13:19,440  
about the detail Hubble can see inside

1628  
01:13:25,129 --> 01:13:22,800  
globular clusters this was not intended

1629  
01:13:27,709 --> 01:13:25,139  
to be a press release image it's a test

1630  
01:13:31,189 --> 01:13:27,719  
image because the blue is ultraviolet

1631  
01:13:33,500 --> 01:13:31,199  
the red is infrared it was a test image

1632  
01:13:36,050 --> 01:13:33,510  
to show off the broad wavelength

1633  
01:13:37,970 --> 01:13:36,060  
coverage of Wide Field Camera 3 the

1634  
01:13:40,640 --> 01:13:37,980  
largest wavelength coverage of any

1635  
01:13:43,040 --> 01:13:40,650  
instrument ever on Hubble to show up but

1636  
01:13:44,990 --> 01:13:43,050  
it was such an amazing image that it

1637  
01:13:47,780 --> 01:13:45,000  
ended up making it wait its way into the

1638  
01:13:51,439 --> 01:13:47,790

press package both of those images were

1639

01:13:55,790 --> 01:13:51,449

featured in the IMAX film Hubble 3d and

1640

01:13:58,580 --> 01:13:55,800

my personal note on this was that when

1641

01:14:02,510 --> 01:13:58,590

the servicing mission was delayed from

1642

01:14:05,660 --> 01:14:02,520

October to May the film's release date

1643

01:14:08,120 --> 01:14:05,670

was not and those of us working on the

1644

01:14:09,950 --> 01:14:08,130

computer graphics for this film had to

1645

01:14:11,840 --> 01:14:09,960

wait until after the servicing mission

1646

01:14:13,879 --> 01:14:11,850

because the IMAX director couldn't pay

1647

01:14:15,950 --> 01:14:13,889

any attention to doing the beautiful

1648

01:14:17,180 --> 01:14:15,960

shots we were doing until after the

1649

01:14:18,979 --> 01:14:17,190

service mission was done and she'd

1650

01:14:21,620 --> 01:14:18,989

gotten the footage from the servicing

1651

01:14:23,330 --> 01:14:21,630

mission to put in the film so that delay

1652

01:14:25,729 --> 01:14:23,340

the servicing mission actually meant we

1653

01:14:28,129 --> 01:14:25,739

had six-month less time to work on the

1654

01:14:29,660 --> 01:14:28,139

computer graphics for the film but we

1655

01:14:30,590 --> 01:14:29,670

still accomplished it was really

1656

01:14:32,660 --> 01:14:30,600

wonderful

1657

01:14:35,120 --> 01:14:32,670

but that delay hit me in a way that I

1658

01:14:37,760 --> 01:14:35,130

had never even expected when it would

1659

01:14:41,000 --> 01:14:37,770

happen but that film has grossed over

1660

01:14:43,850 --> 01:14:41,010

fifty million dollars worldwide which is

1661

01:14:47,390 --> 01:14:43,860

tremendous for a documentary it's on

1662

01:14:51,740 --> 01:14:47,400

track to become one of the top 5 IMAX

1663

01:14:54,080 --> 01:14:51,750

documentary fans of all time 2010 for

1664

01:14:54,979 --> 01:14:54,090

Hubble's 20th anniversary released this

1665

01:14:58,129 --> 01:14:54,989

image which we

1666

01:15:00,379 --> 01:14:58,139

named mystic mountain and it is again

1667

01:15:02,390 --> 01:15:00,389

pillars like the pillars in the Eagle

1668

01:15:04,580 --> 01:15:02,400

Nebula but here you can see we've got

1669

01:15:07,100 --> 01:15:04,590

these jets of materials streaming off up

1670

01:15:08,810 --> 01:15:07,110

here this are what I call the birth

1671

01:15:11,149 --> 01:15:08,820

announcements of a newborn star when

1672

01:15:13,879 --> 01:15:11,159

stars are born they often have these

1673

01:15:15,529 --> 01:15:13,889

twin pillars of jets streaming out and

1674

01:15:19,069 --> 01:15:15,539

you can see up not only here but also

1675

01:15:22,450 --> 01:15:19,079

here again gorgeous ionization fronts

1676

01:15:27,229 --> 01:15:22,460

but this time with jets to show them off

1677

01:15:29,540 --> 01:15:27,239

2011 the galaxies ARP 273 something that

1678

01:15:31,459 --> 01:15:29,550

was nicknamed the rose because these two

1679

01:15:33,859 --> 01:15:31,469

galaxies have been interacting but only

1680

01:15:35,359 --> 01:15:33,869

gently and you can see that this galaxy

1681

01:15:36,799 --> 01:15:35,369

has become stretched out and got a

1682

01:15:39,560 --> 01:15:36,809

little bit of tidal tails up and down

1683

01:15:41,569 --> 01:15:39,570

whereas the spiral arms of this galaxy

1684

01:15:42,979 --> 01:15:41,579

have been stretched out and if you sort

1685

01:15:47,479 --> 01:15:42,989

of squinted it you can see this is the

1686

01:15:49,879 --> 01:15:47,489

stem with the rose up at the top 2011

1687

01:15:52,129 --> 01:15:49,889

also saw the awarding of the Nobel Prize

1688

01:15:54,379 --> 01:15:52,139

in Physics to Adam Riess here at the

1689

01:15:56,689 --> 01:15:54,389

Space Telescope Science Institute and to

1690

01:15:59,000 --> 01:15:56,699

be fair it was awarded for the work he

1691

01:16:01,250 --> 01:15:59,010

did on the accelerating universe before

1692

01:16:04,330 --> 01:16:01,260

he was here but as I mentioned before

1693

01:16:07,040 --> 01:16:04,340

because Hubble played a pivotal role in

1694

01:16:09,169 --> 01:16:07,050

verifying and giving the scientific

1695

01:16:11,180 --> 01:16:09,179

community trust that the accelerating

1696

01:16:13,189 --> 01:16:11,190

universe was correct we like to

1697

01:16:14,899 --> 01:16:13,199

celebrate it - he's also here if you

1698

01:16:17,839 --> 01:16:14,909

want to see a replica of the Nobel Prize

1699

01:16:21,830 --> 01:16:17,849

it's a medal it's out in the lobby and

1700

01:16:23,689 --> 01:16:21,840

you can see it as you go out 2012

1701

01:16:25,759 --> 01:16:23,699

remember that Pluto Charon picture I

1702

01:16:28,310 --> 01:16:25,769

showed you the very beginning from 1990

1703

01:16:29,989 --> 01:16:28,320

well we would be on looking around Pluto

1704

01:16:32,839 --> 01:16:29,999

for the new Horizons mission which will

1705

01:16:36,529 --> 01:16:32,849

get to Pluto in July of this year we

1706

01:16:40,450 --> 01:16:36,539

found not one not two not three but four

1707

01:16:44,149 --> 01:16:40,460

other moons around Pluto and Charon

1708

01:16:46,250 --> 01:16:44,159

basically taking from 2 to 6 the number

1709

01:16:49,729 --> 01:16:46,260

of targets the new Horizons mission has

1710

01:16:51,770 --> 01:16:49,739

to look at so the detail and Hubble with

1711

01:16:53,899 --> 01:16:51,780

its new instruments able to see really

1712

01:16:56,899 --> 01:16:53,909

fine and faint things out at the edge of

1713

01:16:58,759 --> 01:16:56,909

our solar system we can also see really

1714

01:17:00,770 --> 01:16:58,769

fine and faint things out of the edge of

1715

01:17:02,390 --> 01:17:00,780

the universe but for that we're gonna

1716

01:17:04,219 --> 01:17:02,400

use a little bit of help because I talk

1717

01:17:07,100 --> 01:17:04,229

to you about gravitational lensing and

1718

01:17:07,910 --> 01:17:07,110

how there is a lens in space but we can

1719

01:17:10,729 --> 01:17:07,920

use that

1720

01:17:13,040 --> 01:17:10,739

to magnify really distant galaxies and

1721

01:17:17,150 --> 01:17:13,050

see galaxies that Hubble could never

1722

01:17:20,150 --> 01:17:17,160

otherwise see these images [jd1](#) [jt2](#) 283

1723

01:17:22,490 --> 01:17:20,160

are all of the same galaxy that has

1724

01:17:25,520 --> 01:17:22,500

whose light has been not just distorted

1725

01:17:27,590 --> 01:17:25,530

but also magnified so Hubble can see it

1726

01:17:31,340 --> 01:17:27,600

this is the one of the most distant

1727

01:17:36,160 --> 01:17:31,350

galaxy candidates ever discovered at or

1728

01:17:38,270 --> 01:17:36,170

at almost 13 billion light-years away I

1729

01:17:43,220 --> 01:17:38,280

never remember the numbers on those it's

1730

01:17:44,780 --> 01:17:43,230

between 12 and 13 okay ah 2013 we start

1731

01:17:47,390 --> 01:17:44,790

revisiting some images we had taken

1732

01:17:49,850 --> 01:17:47,400

before this is the famed Horsehead

1733

01:17:53,630 --> 01:17:49,860

Nebula which in using visible light has

1734

01:17:55,700 --> 01:17:53,640

a great dark column and there's not much

1735

01:17:58,550 --> 01:17:55,710

to see if there's not much detail in it

1736

01:18:00,950 --> 01:17:58,560

but with the new infrared capability of

1737

01:18:05,689 --> 01:18:00,960

Wide Field Camera 3 we take this same

1738

01:18:08,209 --> 01:18:05,699

image on a larger field and you get a

1739

01:18:11,600 --> 01:18:08,219

glowing gaseous landscape in the

1740

01:18:13,250 --> 01:18:11,610

infrared all sorts of detail shows up in

1741

01:18:15,380 --> 01:18:13,260

when you look in the infrared and see

1742

01:18:17,479 --> 01:18:15,390

the cooler gas and the structures that

1743

01:18:20,479 --> 01:18:17,489

you can see in in the Horsehead Nebula

1744

01:18:21,350 --> 01:18:20,489

we also revisited that Hubble ultra-deep

1745

01:18:23,180 --> 01:18:21,360

field

1746

01:18:26,780 --> 01:18:23,190

we'd been revisiting it in the infrared

1747

01:18:28,610 --> 01:18:26,790

in 2009 and so we were able to get

1748

01:18:31,939 --> 01:18:28,620

further and deeper in the infrared and

1749

01:18:33,830 --> 01:18:31,949

in 2014 we said let's extend that to the

1750

01:18:36,260 --> 01:18:33,840

ultraviolet let's take advantage that we

1751

01:18:37,990 --> 01:18:36,270

have ultraviolet visible and infrared

1752

01:18:41,560 --> 01:18:38,000

and together we Pruce the

1753

01:18:44,709 --> 01:18:41,570

multi-wavelength Ultra Deep Field in

1754

01:18:48,740 --> 01:18:44,719

2014 the deepest image of the universe

1755

01:18:51,680 --> 01:18:48,750

covering a broad spectrum of colors so

1756

01:18:55,010 --> 01:18:51,690

based on all that what are we gonna do

1757

01:18:57,020 --> 01:18:55,020

for the 25th anniversary well for the

1758

01:19:00,470 --> 01:18:57,030

25th anniversary we decided we would

1759

01:19:04,070 --> 01:19:00,480

revisit a classic we would go back to

1760

01:19:06,110 --> 01:19:04,080

that pillars of creation from 1995 and

1761

01:19:07,669 --> 01:19:06,120

you can see how it has that stair-step

1762

01:19:10,820 --> 01:19:07,679

shape due to a wide field planetary

1763

01:19:13,959 --> 01:19:10,830

camera - we would go in with wide field

1764

01:19:17,510 --> 01:19:13,969

camera 3 look at it and I present to you

1765

01:19:22,430 --> 01:19:17,520

the 25th anniversary image the new wisi

1766

01:19:28,740 --> 01:19:25,530

you can see it covers a much larger

1767

01:19:31,140 --> 01:19:28,750

field of view at greater detail twice

1768

01:19:33,540 --> 01:19:31,150

the resolution there's approximately 60

1769

01:19:35,250 --> 01:19:33,550

million pixels of visual goodness for

1770

01:19:37,620 --> 01:19:35,260

you to explore you can see that those

1771

01:19:38,970 --> 01:19:37,630

pillars fade out here but yet new

1772

01:19:40,650 --> 01:19:38,980

pillars are underneath I sort of think

1773

01:19:43,290 --> 01:19:40,660

of this as a it looks like at the tree

1774

01:19:46,320 --> 01:19:43,300

stump underneath it you can also see how

1775

01:19:49,110 --> 01:19:46,330

the gasps fades away as that streaming

1776

01:19:51,030 --> 01:19:49,120

of it pulls the gas off I had a friend

1777

01:19:52,620 --> 01:19:51,040

at the SS who said oh I know what that

1778

01:19:54,990 --> 01:19:52,630

looks like that looks like the Dementors

1779

01:19:59,130 --> 01:19:55,000

from Harry Potter alright so this should

1780

01:20:01,230 --> 01:19:59,140

be the DeMint or pillar oh but let's

1781

01:20:04,110 --> 01:20:01,240

take it one step further because we have

1782

01:20:06,960 --> 01:20:04,120

with c3 it has broad wavelength coverage

1783

01:20:12,900 --> 01:20:06,970

we can look in the infrared and in the

1784

01:20:15,060 --> 01:20:12,910

infrared we see that I talked to you

1785

01:20:16,740 --> 01:20:15,070

about how these pillars have these dense

1786

01:20:18,630 --> 01:20:16,750

regions at the top but aren't

1787

01:20:21,480 --> 01:20:18,640

necessarily dense all the way down here

1788

01:20:23,400 --> 01:20:21,490

you can truly see that there are not

1789

01:20:25,320 --> 01:20:23,410

dense all the way down if I go back to

1790

01:20:28,080 --> 01:20:25,330

the visible light you can see that the

1791

01:20:30,480 --> 01:20:28,090

gas of the nebula obscures all the

1792

01:20:32,670 --> 01:20:30,490

background if we go to the infrared all

1793

01:20:34,380 --> 01:20:32,680

of those background stars start to

1794

01:20:36,750 --> 01:20:34,390

appear you can even see some background

1795

01:20:39,240 --> 01:20:36,760

galaxies in through here take a look at

1796

01:20:41,640 --> 01:20:39,250

these four bright stars they're very

1797

01:20:46,110 --> 01:20:41,650

bright in the infrared but where are

1798

01:20:48,510 --> 01:20:46,120

they in visible light okay looking in

1799

01:20:51,300 --> 01:20:48,520

different wavelengths gives you a whole

1800

01:20:52,830 --> 01:20:51,310

new perspective this is why having

1801

01:20:59,250 --> 01:20:52,840

multi-wavelength coverage is so

1802

01:21:01,290 --> 01:20:59,260

important whoops That's not me there we

1803

01:21:03,780 --> 01:21:01,300

go we're back huh look at

1804

01:21:06,510 --> 01:21:03,790

multi-wavelength is so important to give

1805

01:21:07,980 --> 01:21:06,520

you as many views and many ideas on the

1806

01:21:11,250 --> 01:21:07,990

physics that's going for it

1807

01:21:13,980 --> 01:21:11,260

so over its 25 years Hubble has produced

1808

01:21:16,710 --> 01:21:13,990

an amazing panoply of images it has

1809

01:21:19,500 --> 01:21:16,720

looked at planets and stars and nebulae

1810

01:21:21,750 --> 01:21:19,510

and galaxies and all the way across the

1811

01:21:24,870 --> 01:21:21,760

universe but this is a scientific

1812

01:21:27,960 --> 01:21:24,880

telescope and the true measure of Hubble

1813

01:21:32,730 --> 01:21:27,970

of course has to be the science so

1814

01:21:34,190 --> 01:21:32,740

here's a plot we made a back in 2011 to

1815

01:21:37,820 --> 01:21:34,200

celebrate

1816

01:21:40,190 --> 01:21:37,830

the scientific publication the bubbles

1817

01:21:42,200 --> 01:21:40,200

scientific publication record so we have

1818

01:21:43,820 --> 01:21:42,210

the number of refereed science papers

1819

01:21:45,650 --> 01:21:43,830

notice that these are refereed these

1820

01:21:47,540 --> 01:21:45,660

aren't just papers written they have

1821

01:21:50,270 --> 01:21:47,550

been refereed by other scientists and

1822

01:21:54,530 --> 01:21:50,280

over the course of its history these are

1823

01:21:56,690 --> 01:21:54,540

per year okay we're getting up six seven

1824

01:22:00,260 --> 01:21:56,700

hundred papers this plot was produced to

1825

01:22:04,340 --> 01:22:00,270

celebrate the 10,000 refereed scientific

1826

01:22:07,610 --> 01:22:04,350

paper by today we are over 12,000

1827

01:22:10,250 --> 01:22:07,620

refereed scientific papers this is where

1828

01:22:12,080 --> 01:22:10,260

you as taxpayers are getting the bang

1829

01:22:15,220 --> 01:22:12,090

for your buck yes you enjoy the pretty

1830

01:22:18,920 --> 01:22:15,230

pictures but the fact that we have

1831

01:22:22,160 --> 01:22:18,930

changed science across all scales of

1832

01:22:27,080 --> 01:22:22,170

astronomy with this many refereed papers

1833

01:22:28,850 --> 01:22:27,090

is the true value of Hubble so I'm going

1834

01:22:34,820 --> 01:22:28,860

to finish with one of my favorite images

1835

01:22:37,550 --> 01:22:34,830

of Hubble it to me is hopeful it is

1836

01:22:40,100 --> 01:22:37,560

looking up staring out at the universe

1837

01:22:43,570 --> 01:22:40,110

and it has that hopeful feeling to it

1838

01:22:46,810 --> 01:22:43,580

and you may think that after 25 years

1839

01:22:51,410 --> 01:22:46,820

Hubble is old Hubble has been around

1840

01:22:54,560 --> 01:22:51,420

okay it's it's on its downside but I

1841

01:22:56,630 --> 01:22:54,570

gotta tell you that while the

1842

01:22:59,720 --> 01:22:56,640

instruments may be older the telescope

1843

01:23:01,820 --> 01:22:59,730

may be older the scientists and the

1844

01:23:05,710 --> 01:23:01,830

computer programmers and the ability to

1845

01:23:08,720 --> 01:23:05,720

use the telescope has only gotten better

1846

01:23:11,240 --> 01:23:08,730

our understanding of how to use the

1847

01:23:13,190 --> 01:23:11,250

telescope to preserve the batteries how

1848

01:23:15,980 --> 01:23:13,200

to use the telescope to dude use the

1849

01:23:19,160 --> 01:23:15,990

gyros we can go down if we lose for

1850

01:23:21,680 --> 01:23:19,170

gyros we can operate and do 95% of the

1851

01:23:24,260 --> 01:23:21,690

science in to gyro mode we've even

1852

01:23:28,130 --> 01:23:24,270

figured out how to do 60% of the science

1853

01:23:31,220 --> 01:23:28,140

in one gyro mode okay our scheduling has

1854

01:23:34,040 --> 01:23:31,230

gone from approximately two months down

1855

01:23:36,320 --> 01:23:34,050

to less than two weeks for utilizing

1856

01:23:40,400 --> 01:23:36,330

this telescopes we keep gaining

1857

01:23:42,500 --> 01:23:40,410

efficiencies and last year five years

1858

01:23:44,600 --> 01:23:42,510

after servicing mission 4 when the

1859

01:23:47,630 --> 01:23:44,610

warranty on servicing mission 4 had run

1860

01:23:47,970 --> 01:23:47,640

out a top official in this building said

1861

01:23:51,390 --> 01:23:47,980

you know

1862

01:23:55,080 --> 01:23:51,400

what Hubble is actually at its greatest

1863

01:23:57,450 --> 01:23:55,090

power now than it has ever been because

1864

01:24:00,390 --> 01:23:57,460

of the efficiencies we are learning and

1865

01:24:02,250 --> 01:24:00,400

key in utilizing this telescope so I

1866

01:24:05,250 --> 01:24:02,260

have always said I want to see Hubble

1867

01:24:07,229 --> 01:24:05,260

live to 2020 I want to have it still up

1868

01:24:09,390 --> 01:24:07,239

and flying and actively observing when

1869

01:24:11,430 --> 01:24:09,400

the James Webb Space Telescope is up

1870

01:24:14,420 --> 01:24:11,440

that would be fantastic then we could

1871

01:24:16,770 --> 01:24:14,430

have two nasa's flagship missions

1872

01:24:19,890 --> 01:24:16,780

observing one an over the physical light

1873

01:24:22,440 --> 01:24:19,900

one in the infrared to really get pinned

1874

01:24:24,750 --> 01:24:22,450

down ideas because webb will have hubble

1875

01:24:28,950 --> 01:24:24,760

resolution in across the infrared

1876  
01:24:30,570 --> 01:24:28,960  
spectrum but you know what i'm possibly

1877  
01:24:32,880 --> 01:24:30,580  
starting to think that maybe we could go

1878  
01:24:34,979 --> 01:24:32,890  
a bit further right I started giving

1879  
01:24:37,020 --> 01:24:34,989  
these retrospective talks at Hubble 15

1880  
01:24:39,210 --> 01:24:37,030  
back when the servicing mission 4 was

1881  
01:24:41,910 --> 01:24:39,220  
cancelled and I gave one at Hubble 20

1882  
01:24:44,280 --> 01:24:41,920  
and I'm giving it a Hubble 25 I hope to

1883  
01:24:48,180 --> 01:24:44,290  
see you all here for Hubble 30 and dare

1884  
01:24:51,450 --> 01:24:48,190  
I even think about Hubble 35 I don't

1885  
01:24:53,460 --> 01:24:51,460  
know I just have to say that I in my

1886  
01:24:55,830 --> 01:24:53,470  
years here have been amazing

1887  
01:24:58,050 --> 01:24:55,840  
early impressed with the dedication and

1888  
01:25:02,990 --> 01:24:58,060

the professionalism of the staff here

1889

01:25:06,420 --> 01:25:03,000

they do an amazing job Hubble has

1890

01:25:07,740 --> 01:25:06,430

transcended astronomy I can say Hubble

1891

01:25:10,260 --> 01:25:07,750

and the public knows what we're talking

1892

01:25:11,700 --> 01:25:10,270

about you can't talk about a particle

1893

01:25:14,310 --> 01:25:11,710

accelerator or a scanning electron

1894

01:25:16,380 --> 01:25:14,320

microscope in the same way all right

1895

01:25:18,900 --> 01:25:16,390

it is part of the public public

1896

01:25:21,390 --> 01:25:18,910

vernacular so it has changed astronomy

1897

01:25:23,760 --> 01:25:21,400

it has changed our view and changed our

1898

01:25:25,229 --> 01:25:23,770

understanding and I hope you will join

1899

01:25:27,930 --> 01:25:25,239

with us this year in celebrating its

1900

01:25:31,350 --> 01:25:27,940

25th anniversary as I like to call it a

1901

01:25:53,850 --> 01:25:31,360

celestial silver celebration thank you

1902

01:25:59,320 --> 01:25:57,340

okay part of my own rules I have four

1903

01:26:01,510 --> 01:25:59,330

minutes for questions it was like to ask

1904

01:26:04,240 --> 01:26:01,520

any questions otherwise I have to pull

1905

01:26:05,980 --> 01:26:04,250

myself offstage so do we have any

1906

01:26:08,260 --> 01:26:05,990

questions that I can answer I know I

1907

01:26:10,210 --> 01:26:08,270

talked long but I'm sorry there's just

1908

01:26:17,590 --> 01:26:10,220

so much cool stop to joke yes right

1909

01:26:19,330 --> 01:26:17,600

there earth hole has an infinite focus

1910

01:26:21,220 --> 01:26:19,340

it's pointed out into the universe

1911

01:26:22,930 --> 01:26:21,230

the closest thing it's ever observed is

1912

01:26:24,970 --> 01:26:22,940

the moon okay

1913

01:26:28,510 --> 01:26:24,980

Hubble would be useless pointed towards

1914

01:26:29,860 --> 01:26:28,520

Earth and besides the other parts of the

1915

01:26:55,900 --> 01:26:29,870

government have much better ones for

1916

01:26:57,790 --> 01:26:55,910

doing either the Hubble Deep Field or

1917

01:26:59,260 --> 01:26:57,800

the Hubble Ultra Deep Field if you

1918

01:27:01,360 --> 01:26:59,270

thought you saw gravitational lensing in

1919

01:27:09,340 --> 01:27:01,370

the Hubble Deep Field it may have been

1920

01:27:11,110 --> 01:27:09,350

an artifact so you get gravitational

1921

01:27:12,370 --> 01:27:11,120

lensing so the question is how come

1922

01:27:14,020 --> 01:27:12,380

there is gravitational lensing and some

1923

01:27:15,850 --> 01:27:14,030

images you get brevity of lungeing when

1924

01:27:18,670 --> 01:27:15,860

you have a cluster of galaxies providing

1925

01:27:20,920 --> 01:27:18,680

the mass to do the lensing as the mass

1926

01:27:22,360 --> 01:27:20,930

creates the lensing the Hubble Deep

1927

01:27:25,390 --> 01:27:22,370

Field and the Hubble ultra-deep field

1928

01:27:27,310 --> 01:27:25,400

were chosen to look in regions where

1929

01:27:29,380 --> 01:27:27,320

there was there would be no large

1930

01:27:31,780 --> 01:27:29,390

clusters in Matta fact we tried to find

1931

01:27:33,220 --> 01:27:31,790

the emptiest spots in the sky so that we

1932

01:27:34,330 --> 01:27:33,230

can see as far to the universe as

1933

01:27:36,520 --> 01:27:34,340

possible we're trying to get rid of all

1934

01:27:39,520 --> 01:27:36,530

the Milky Way stars although Milky Way

1935

01:27:41,470 --> 01:27:39,530

gasps all of the known galaxies and

1936

01:27:43,600 --> 01:27:41,480

clusters so we didn't look at in those

1937

01:27:45,130 --> 01:27:43,610

regions it actually is an exercise in

1938

01:27:53,380 --> 01:27:45,140

trying to find the most boring part in

1939

01:27:54,700 --> 01:27:53,390

this part of the sky you can find all

1940

01:27:55,810 --> 01:27:54,710

right so he starts out with it if

1941

01:27:58,000 --> 01:27:55,820

there's ever a servicing mission

1942

01:27:59,680 --> 01:27:58,010

approved we have no shuttle program so

1943

01:28:04,590 --> 01:27:59,690

there isn't a servicing mission approved

1944

01:28:13,290 --> 01:28:08,500

what do you think NASA Institute would

1945

01:28:18,700 --> 01:28:16,210

well we are not working on any insight

1946

01:28:21,160 --> 01:28:18,710

so the question is can we improve Hubble

1947

01:28:22,960 --> 01:28:21,170

if there was some impossible chance say

1948

01:28:25,240 --> 01:28:22,970

Elon Musk decided that he it was gonna

1949

01:28:28,990 --> 01:28:25,250

go to Hubble okay I damned he could do

1950

01:28:30,640 --> 01:28:29,000

anything right we would have to develop

1951

01:28:32,650 --> 01:28:30,650

instruments

1952

01:28:34,890 --> 01:28:32,660

whoever would try and service it would

1953

01:28:38,470 --> 01:28:34,900

have to develop a entire suite of

1954

01:28:40,330 --> 01:28:38,480

servicing materials I mean Hubble was

1955

01:28:43,030 --> 01:28:40,340

designed to be serviced in the shuttle

1956

01:28:44,890 --> 01:28:43,040

cargo bay it has the the lazy susan

1957

01:28:46,950 --> 01:28:44,900

there and all the instrumentation and

1958

01:28:49,900 --> 01:28:46,960

everything designed to work with Hubble

1959

01:28:53,260 --> 01:28:49,910

to recreate that would be well nigh

1960

01:28:55,240 --> 01:28:53,270

impossible so that's one thing but in

1961

01:28:58,270 --> 01:28:55,250

order to improve Hubble we would have to

1962

01:29:00,280 --> 01:28:58,280

be developing the repair parts or the

1963

01:29:02,820 --> 01:29:00,290

the new instruments which are not being

1964

01:29:06,940 --> 01:29:02,830

developed and those take several years

1965

01:29:10,870 --> 01:29:06,950

people worked on ACS for five to seven

1966

01:29:12,940 --> 01:29:10,880

years before it launched so it takes

1967

01:29:15,070 --> 01:29:12,950

quite some time to do that so it would

1968

01:29:17,260 --> 01:29:15,080

have to be a concerted effort and would

1969

01:29:18,550 --> 01:29:17,270

have a long long lead time if such a

1970

01:29:22,150 --> 01:29:18,560

thing were possible but I don't think

1971

01:29:25,210 --> 01:29:22,160

leave it is yes what the president plan

1972

01:29:27,070 --> 01:29:25,220

for deorbiting there's no way to the

1973

01:29:29,740 --> 01:29:27,080

present plan for new orbiting Hubble is

1974

01:29:31,950 --> 01:29:29,750

to have a robotic mission during

1975

01:29:33,910 --> 01:29:31,960

servicing mission fourth they they

1976

01:29:35,980 --> 01:29:33,920

installed on the bottom of how well

1977

01:29:39,160 --> 01:29:35,990

something called the SCM soft soft

1978

01:29:40,720 --> 01:29:39,170

capture mechanism so that a robotic

1979

01:29:43,210 --> 01:29:40,730

mission could go up and grapple with

1980

01:29:46,360 --> 01:29:43,220

Hubble and then deorbit it safely oh

1981

01:29:48,100 --> 01:29:46,370

there's the picture is already there yes

1982

01:29:49,960 --> 01:29:48,110

the fixture is already there on Hubble

1983

01:29:54,220 --> 01:29:49,970

now is there a mission plan to do that

1984

01:29:58,510 --> 01:29:54,230

no we'll all of us start crying if that

1985

01:30:02,200 --> 01:29:58,520

happens yes much else we can do right

1986

01:30:04,840 --> 01:30:02,210

now no because we have to do it it

1987

01:30:07,450 --> 01:30:04,850

safely okay after our after space lab in

1988

01:30:09,860 --> 01:30:07,460

the 1970s we learned our lesson we're

1989

01:30:13,520 --> 01:30:09,870

not going to let things come in

1990

01:30:16,550 --> 01:30:13,530

and uncontrolled deorbit right so if we

1991

01:30:18,170 --> 01:30:16,560

can't find some way to do something else

1992

01:30:22,040 --> 01:30:18,180

with Hubble it will have to be deorbited

1993

01:30:25,010 --> 01:30:22,050

safely right you could attach a kind of

1994

01:30:26,600 --> 01:30:25,020

a new boost mechanism on that girl a lot

1995

01:30:29,060 --> 01:30:26,610

of people would love to take Hubble and

1996

01:30:30,290 --> 01:30:29,070

just boost it to a really high orbit and

1997

01:30:32,710 --> 01:30:30,300

let it sit there for a hundred years

1998

01:30:34,550 --> 01:30:32,720

until we figure out something better

1999

01:30:36,920 --> 01:30:34,560

don't know if that's possible either

2000

01:30:40,400 --> 01:30:36,930

okay that's something an Elon Musk would

2001

01:30:43,760 --> 01:30:40,410

probably have you be useful for all

2002

01:30:45,710 --> 01:30:43,770

right one last question I got one last

2003

01:30:47,240 --> 01:30:45,720

question is there somebody from the

2004

01:30:51,520 --> 01:30:47,250

Maryland Space Grant Observatory here

2005

01:30:53,120 --> 01:30:51,530

today to take people across the street

2006

01:30:54,590 --> 01:30:53,130

no there isn't

2007

01:31:03,130 --> 01:30:54,600

what's here in the back did you have a

2008

01:31:13,580 --> 01:31:07,820

yeah what do you what do you think about

2009

01:31:15,350 --> 01:31:13,590

the movie interstellar I have not seen

2010

01:31:17,450 --> 01:31:15,360

the movie interstellar have a theory of

2011

01:31:22,730 --> 01:31:17,460

everything I have not seen this theory

2012

01:31:24,710 --> 01:31:22,740

of everything I getting ready for the

2013

01:31:27,200 --> 01:31:24,720

astronomical American Astronomical

2014

01:31:29,780 --> 01:31:27,210

Society meeting in Seattle and also I

2015

01:31:32,810 --> 01:31:29,790

promised the IMAX director I work with

2016

01:31:35,210 --> 01:31:32,820

that I would see interstellar on IMAX

2017

01:31:37,550 --> 01:31:35,220

not just go out to any any movie theater

2018

01:31:39,380 --> 01:31:37,560

because Christopher Nolan the director

2019

01:31:42,170 --> 01:31:39,390

loves IMAX and shot a lot of it with

2020

01:31:44,180 --> 01:31:42,180

IMAX and so I promised Tony that I would