

1
00:00:00,590 --> 00:00:14,140
[Music]

2
00:00:15,679 --> 00:00:20,189
hi I'm dr. Frank summers of the Space

3
00:00:18,719 --> 00:00:22,528
Telescope Science Institute

4
00:00:20,189 --> 00:00:25,500
welcome to Hubble's universe unfiltered

5
00:00:22,528 --> 00:00:26,099
or perhaps I should be saying welcome

6
00:00:25,500 --> 00:00:27,929
back

7
00:00:26,099 --> 00:00:30,240
we've been on hiatus for several months

8
00:00:27,929 --> 00:00:32,519
but there's a really good reason why

9
00:00:30,239 --> 00:00:36,750
we're on hiatus we were working on the

10
00:00:32,520 --> 00:00:37,649
IMAX film Hubble 3d myself and gentlemen

11
00:00:36,750 --> 00:00:39,808
behind the camera

12
00:00:37,649 --> 00:00:42,989
we're heavily involved in creating the

13
00:00:39,808 --> 00:00:46,280
sequences of Hubble imagery in 3d for

14
00:00:42,988 --> 00:00:49,709
that film the film came out in March of

15
00:00:46,280 --> 00:00:51,960
2010 and our work on that film will be

16
00:00:49,710 --> 00:00:54,808
the subject of some upcoming episodes of

17
00:00:51,960 --> 00:00:56,969
Hubble's universe unfiltered for today's

18
00:00:54,808 --> 00:00:58,828
episode I'd like to talk about another

19
00:00:56,969 --> 00:01:02,280
special event that we had this spring

20
00:00:58,829 --> 00:01:06,420
Hubble's 20th anniversary this image

21
00:01:02,280 --> 00:01:08,368
shows you April 24th 1990 the launch of

22
00:01:06,420 --> 00:01:12,210
the space shuttle Discovery carrying

23
00:01:08,368 --> 00:01:15,209
Hubble a lot into space and on this

24
00:01:12,209 --> 00:01:17,489
service shuttle mission put Hubble into

25
00:01:15,209 --> 00:01:19,859
orbit into its platform from which it

26
00:01:17,489 --> 00:01:22,649
observes the universe it has been up for

27
00:01:19,859 --> 00:01:25,140
20 years now taking an incredible number

28
00:01:22,650 --> 00:01:27,900
of observations so how does one

29

00:01:25,140 --> 00:01:31,349
celebrate 20 years of such an amazing

30
00:01:27,900 --> 00:01:34,799
telescope well I was asked to come up

31
00:01:31,349 --> 00:01:36,419
with 20 images to sort of show the

32
00:01:34,799 --> 00:01:40,368
breadth and depth of what Hubble has

33
00:01:36,420 --> 00:01:43,259
done over over its observing history and

34
00:01:40,368 --> 00:01:44,969
the first idea was to come up with all

35
00:01:43,259 --> 00:01:47,879
the most scientific interesting images

36
00:01:44,969 --> 00:01:49,798
well the most scientifically significant

37
00:01:47,879 --> 00:01:52,199
images oftentimes aren't the most

38
00:01:49,799 --> 00:01:54,750
beautiful images and it often takes an

39
00:01:52,200 --> 00:01:56,670
entire episode of this video podcast in

40
00:01:54,750 --> 00:01:59,549
order to explain why these images are so

41
00:01:56,670 --> 00:02:02,368
significant the other idea would be then

42
00:01:59,549 --> 00:02:04,469
to go for the most beautiful images well

43
00:02:02,368 --> 00:02:06,030

then you tend to look only at the later

44

00:02:04,468 --> 00:02:08,128

part of Hubble's life when we had the

45

00:02:06,030 --> 00:02:09,929

newer instruments on Hubble and you sort

46

00:02:08,128 --> 00:02:12,628

of ignore the early parts of Hubble's

47

00:02:09,929 --> 00:02:13,090

observations so what we ended up coming

48

00:02:12,628 --> 00:02:15,579

up

49

00:02:13,090 --> 00:02:18,819

is sort of a combination of those images

50

00:02:15,580 --> 00:02:21,550

that cover the full 20 years of Hubble

51

00:02:18,818 --> 00:02:23,348

that cover all of the different subjects

52

00:02:21,550 --> 00:02:27,189

that Hubble has looked at from planets

53

00:02:23,348 --> 00:02:29,829

to stars to nebulae to galaxies and one

54

00:02:27,189 --> 00:02:31,389

that sort of covers the breadth of how

55

00:02:29,830 --> 00:02:34,480

much we've done in terms of science and

56

00:02:31,389 --> 00:02:36,369

significance as well as beauty now

57

00:02:34,479 --> 00:02:38,709

there's something that I had to get out

58
00:02:36,370 --> 00:02:40,750
of the way right away is that after

59
00:02:38,709 --> 00:02:42,580
Hubble was put into orbit there was the

60
00:02:40,750 --> 00:02:44,769
flaw on the mirror and it's sort of a

61
00:02:42,580 --> 00:02:46,630
mythos that Hubble was unusable for the

62
00:02:44,769 --> 00:02:49,989
first few years until that flaw was

63
00:02:46,629 --> 00:02:52,719
corrected that's not true and you can

64
00:02:49,989 --> 00:02:55,420
see in this image of a double star that

65
00:02:52,719 --> 00:02:58,750
Hubble did provide advantages during its

66
00:02:55,419 --> 00:03:00,759
first few years on this side you see a

67
00:02:58,750 --> 00:03:03,430
double star as observed from the ground

68
00:03:00,759 --> 00:03:05,469
and you can see here that it's really

69
00:03:03,430 --> 00:03:06,310
just one blob and the two stars are

70
00:03:05,469 --> 00:03:09,009
merged together

71
00:03:06,310 --> 00:03:10,870
that's because from the ground we have

72
00:03:09,009 --> 00:03:12,639
the atmosphere in between us which

73
00:03:10,870 --> 00:03:13,480
limits our resolution to about one

74
00:03:12,639 --> 00:03:16,029
arcsecond

75
00:03:13,479 --> 00:03:18,159
on the other side we have Hubble's

76
00:03:16,030 --> 00:03:20,259
observation of the exact same double

77
00:03:18,159 --> 00:03:22,180
star and you can see that although the

78
00:03:20,259 --> 00:03:24,310
stars aren't the perfect little

79
00:03:22,180 --> 00:03:27,760
pinpoints we want them to be you can

80
00:03:24,310 --> 00:03:29,650
resolve the two stars even with the flaw

81
00:03:27,759 --> 00:03:32,620
on the mirror Hubble had finer

82
00:03:29,650 --> 00:03:35,079
resolution than any telescope from the

83
00:03:32,620 --> 00:03:36,549
ground so Hubble was able to do good

84
00:03:35,079 --> 00:03:39,489
science for the first three years before

85
00:03:36,549 --> 00:03:42,969
it was repaired and as one example from

86

00:03:39,489 --> 00:03:47,019
1992 is this image of the galaxy Messier

87
00:03:42,969 --> 00:03:49,419
87 now Messier 87 is a giant optical

88
00:03:47,019 --> 00:03:51,250
galaxy contains you know hundreds of

89
00:03:49,419 --> 00:03:54,759
billions of stars maybe even a trillion

90
00:03:51,250 --> 00:03:57,430
stars and at its core is a very bright

91
00:03:54,759 --> 00:04:00,939
source that we believe to be a super

92
00:03:57,430 --> 00:04:03,849
massive black hole this is a matte black

93
00:04:00,939 --> 00:04:06,039
hole with many perhaps even a billion

94
00:04:03,849 --> 00:04:09,430
solar masses a billion times the mass of

95
00:04:06,039 --> 00:04:11,379
our Sun in a black hole and with all the

96
00:04:09,430 --> 00:04:13,030
materials swirling around it and all the

97
00:04:11,379 --> 00:04:16,209
energy of that supermassive black hole

98
00:04:13,030 --> 00:04:18,430
it is spewing out this incredibly jet of

99
00:04:16,209 --> 00:04:21,009
radiation from that supermassive black

100
00:04:18,430 --> 00:04:24,069

hole and Hubble was able to take a

101

00:04:21,009 --> 00:04:26,589

highly resolved view of that super matte

102

00:04:24,069 --> 00:04:31,779

of that jet in galaxies

103

00:04:26,589 --> 00:04:34,000

Messier 87 well in 1993 we did have

104

00:04:31,779 --> 00:04:36,489

servicing mission one and the astronauts

105

00:04:34,000 --> 00:04:38,649

went up and this picture is of them

106

00:04:36,490 --> 00:04:40,360

either taking out Wide Field Camera one

107

00:04:38,649 --> 00:04:42,969

or putting in wide field planetary

108

00:04:40,360 --> 00:04:44,650

camera - that's kind of hard to tell

109

00:04:42,970 --> 00:04:48,430

because they look pretty much exactly

110

00:04:44,649 --> 00:04:50,859

alike wide field planetary camera - had

111

00:04:48,430 --> 00:04:52,478

the correction for the flaw in the

112

00:04:50,860 --> 00:04:55,180

mirror already built into it the

113

00:04:52,478 --> 00:04:57,099

astronauts also put in an instrument

114

00:04:55,180 --> 00:04:59,050

called co-star which had basically

115
00:04:57,100 --> 00:05:02,200
eyeglasses for the other instruments and

116
00:04:59,050 --> 00:05:05,379
that gave Hubble back the resolution was

117
00:05:02,199 --> 00:05:07,029
supposed to have so this next image is I

118
00:05:05,379 --> 00:05:10,839
sometimes jokingly call the most

119
00:05:07,029 --> 00:05:13,269
important Hubble image ever because this

120
00:05:10,839 --> 00:05:16,179
shows you that the repair was successful

121
00:05:13,269 --> 00:05:18,609
on this side we see an image from wide

122
00:05:16,180 --> 00:05:21,668
field planetary camera one of the core

123
00:05:18,610 --> 00:05:24,069
of the galaxy Messier 100 and you can

124
00:05:21,668 --> 00:05:27,639
see the structure in there but you can't

125
00:05:24,069 --> 00:05:29,110
see all the fine details on this side we

126
00:05:27,639 --> 00:05:31,780
see the image from wide field planetary

127
00:05:29,110 --> 00:05:34,509
camera - which had the correction and

128
00:05:31,779 --> 00:05:37,750
you can see voila all of the incredible

129

00:05:34,509 --> 00:05:39,430

details this is the fine detail for

130

00:05:37,750 --> 00:05:42,490

which the Hubble images are really known

131

00:05:39,430 --> 00:05:44,560

and sort of crispness that characterizes

132

00:05:42,490 --> 00:05:48,098

all the Hubble images you've seen over

133

00:05:44,560 --> 00:05:50,319

the decades so this image really said to

134

00:05:48,098 --> 00:05:51,909

the astronomical community yes

135

00:05:50,319 --> 00:05:54,399

Hubble is achieving its design

136

00:05:51,910 --> 00:05:56,020

specifications and from there on it was

137

00:05:54,399 --> 00:05:59,019

able to do the science that we

138

00:05:56,019 --> 00:06:02,500

originally hoped it would do so here

139

00:05:59,019 --> 00:06:05,009

come a slew of images but actually there

140

00:06:02,500 --> 00:06:09,038

was a wonderful case of serendipity in

141

00:06:05,009 --> 00:06:11,379

1994 because in 1993 comet

142

00:06:09,038 --> 00:06:14,228

shoemaker-levy 9 went into orbit around

143

00:06:11,379 --> 00:06:17,139
Jupiter and it broke up into 20 or 30

144
00:06:14,228 --> 00:06:21,279
pieces and it was calculated to hit

145
00:06:17,139 --> 00:06:23,228
Jupiter in July of 1994 it was a very

146
00:06:21,279 --> 00:06:24,759
nice comment because it waited until

147
00:06:23,228 --> 00:06:27,659
Hubble had been repaired

148
00:06:24,759 --> 00:06:30,759
so that Hubble could take gorgeous and

149
00:06:27,660 --> 00:06:33,250
highly detailed images of impact sites

150
00:06:30,759 --> 00:06:35,800
you see those impact sites here in the

151
00:06:33,250 --> 00:06:37,839
lower part of Jupiter and in visible

152
00:06:35,800 --> 00:06:40,060
light they show up as basically big

153
00:06:37,839 --> 00:06:44,299
brown clouds in its atmosphere

154
00:06:40,060 --> 00:06:46,459
in ultraviolet light on this side you

155
00:06:44,300 --> 00:06:48,560
can see that the holes in Jupiter's

156
00:06:46,459 --> 00:06:52,399
atmosphere are actually much larger and

157
00:06:48,560 --> 00:06:55,250

it's important that ultraviolet light is

158

00:06:52,399 --> 00:06:56,719

not viewable from the ground I know you

159

00:06:55,250 --> 00:06:58,819

think you get lots of ultraviolet light

160

00:06:56,720 --> 00:07:00,620

when you get suntan most of the

161

00:06:58,819 --> 00:07:02,930

ultraviolet light is absorbed by Earth's

162

00:07:00,620 --> 00:07:05,120

atmosphere so to do astronomical

163

00:07:02,930 --> 00:07:07,850

observations of ultraviolet light you

164

00:07:05,120 --> 00:07:09,889

must get up into space and Hubble's

165

00:07:07,850 --> 00:07:12,410

platform in space allowed it to view

166

00:07:09,889 --> 00:07:14,899

these impact site in ultraviolet and see

167

00:07:12,410 --> 00:07:16,640

the real detail by the way this is not

168

00:07:14,899 --> 00:07:18,829

an impact site this is just the shadow

169

00:07:16,639 --> 00:07:20,469

of one of Jupiter's moons going across

170

00:07:18,829 --> 00:07:25,339

the surface of Jupiter

171

00:07:20,470 --> 00:07:27,590

well 1995 was a watershed image that

172
00:07:25,339 --> 00:07:29,750
came out called the pillars in the Eagle

173
00:07:27,589 --> 00:07:32,359
Nebula some people call this the pillars

174
00:07:29,750 --> 00:07:34,699
of creation and what's going on here is

175
00:07:32,360 --> 00:07:37,009
that there is dense gas inside these

176
00:07:34,699 --> 00:07:38,629
pillars that is being illuminated by

177
00:07:37,009 --> 00:07:40,699
some bright stars that are up here

178
00:07:38,629 --> 00:07:43,069
matter of fact the high-energy radiation

179
00:07:40,699 --> 00:07:44,930
from those bright stars and winds from

180
00:07:43,069 --> 00:07:47,180
those stars are sweeping across this

181
00:07:44,930 --> 00:07:50,060
region blowing away all the low-density

182
00:07:47,180 --> 00:07:53,720
gas leaving the high-density gas in

183
00:07:50,060 --> 00:07:56,750
these pillars and this gas is such high

184
00:07:53,720 --> 00:07:58,160
density that stars are forming and you

185
00:07:56,750 --> 00:08:00,019
can see at the top of this tallest

186
00:07:58,160 --> 00:08:03,200
pillar that there are little fingers

187
00:08:00,019 --> 00:08:06,649
here and that is where individual stars

188
00:08:03,199 --> 00:08:09,050
are forming this image really you know

189
00:08:06,649 --> 00:08:11,779
captured people's imagination and is

190
00:08:09,050 --> 00:08:16,310
perhaps the most famous of all of the

191
00:08:11,779 --> 00:08:19,669
Hubble images 1996 we captured this

192
00:08:16,310 --> 00:08:23,089
amazing image this is of the dying star

193
00:08:19,670 --> 00:08:25,490
a de Carina now the star is deeply

194
00:08:23,089 --> 00:08:28,399
embedded in here and what you see more

195
00:08:25,490 --> 00:08:30,710
is the lobes of gas that have been blown

196
00:08:28,399 --> 00:08:33,168
out from the star during its death

197
00:08:30,709 --> 00:08:36,348
throes this star is believed to be a

198
00:08:33,168 --> 00:08:40,220
hundred to 150 times the mass of our Sun

199
00:08:36,349 --> 00:08:43,220
and sometime in the next million to ten

200

00:08:40,220 --> 00:08:45,830
million years we expect this star will

201
00:08:43,220 --> 00:08:49,250
explode it will go as a supernova and to

202
00:08:45,830 --> 00:08:52,820
basically blow its guts across space so

203
00:08:49,250 --> 00:08:53,820
this is a star in its preliminary depth

204
00:08:52,820 --> 00:08:58,570
for

205
00:08:53,820 --> 00:09:01,028
well 1997 was the year of our second

206
00:08:58,570 --> 00:09:03,100
servicing mission to Hubble and in terms

207
00:09:01,028 --> 00:09:05,110
of imaging we put in two brand-new

208
00:09:03,100 --> 00:09:07,300
instruments the near infrared camera

209
00:09:05,110 --> 00:09:09,009
multi-object spectrograph which we

210
00:09:07,299 --> 00:09:11,500
usually just call Nick Moss that was an

211
00:09:09,009 --> 00:09:13,838
infrared camera and the Space Telescope

212
00:09:11,500 --> 00:09:17,528
imaging spectrograph which we usually

213
00:09:13,839 --> 00:09:19,660
call stiffs which had both ultraviolet

214
00:09:17,528 --> 00:09:22,559

and visible-light coverage but was

215

00:09:19,659 --> 00:09:25,419

especially sensitive in the ultraviolet

216

00:09:22,559 --> 00:09:27,969

that ultraviolet capability showed up

217

00:09:25,419 --> 00:09:30,849

the next year in this image of Saturn

218

00:09:27,970 --> 00:09:33,820

this is an ultraviolet image of Saturn

219

00:09:30,850 --> 00:09:36,490

and in particular of the Aurora on

220

00:09:33,820 --> 00:09:38,649

Saturn now you got to recognize that

221

00:09:36,490 --> 00:09:41,829

Saturn is about ten times farther away

222

00:09:38,649 --> 00:09:45,339

from the Sun than Earth is and so the

223

00:09:41,828 --> 00:09:48,969

solar wind is expected to be about 1/100

224

00:09:45,339 --> 00:09:50,350

the density it is at earth so we did not

225

00:09:48,970 --> 00:09:53,740

expect that the solar wind will be

226

00:09:50,350 --> 00:09:56,409

strong enough to produce a lot of Aurora

227

00:09:53,740 --> 00:09:59,110

on Saturn however when we look at these

228

00:09:56,409 --> 00:10:01,088

images the power in Saturn's Aurora as

229
00:09:59,110 --> 00:10:04,180
well as the changes in Saturn's roar

230
00:10:01,089 --> 00:10:06,579
surprised us as astronomers and using

231
00:10:04,179 --> 00:10:11,469
ultraviolet capabilities of Hubble we're

232
00:10:06,578 --> 00:10:13,469
able to study that in 1999 we got this

233
00:10:11,470 --> 00:10:16,240
wonderful image of a globular cluster

234
00:10:13,470 --> 00:10:18,600
now a globular cluster is a dense

235
00:10:16,240 --> 00:10:22,539
collection of stars this one has about

236
00:10:18,600 --> 00:10:24,850
50,000 stars its name is Messier 80 and

237
00:10:22,539 --> 00:10:27,819
all of these stars are orbiting around

238
00:10:24,850 --> 00:10:29,110
one another it's important to have high

239
00:10:27,820 --> 00:10:31,629
resolution when you are studying

240
00:10:29,110 --> 00:10:33,159
globular clusters because you see at the

241
00:10:31,629 --> 00:10:35,559
center of this image it sort of blown

242
00:10:33,159 --> 00:10:36,698
out it's all white you can't make out

243
00:10:35,559 --> 00:10:38,768
individual stars

244
00:10:36,698 --> 00:10:40,149
well that's true in all globular

245
00:10:38,769 --> 00:10:42,490
clusters that they're all very dense

246
00:10:40,149 --> 00:10:45,159
than the core and Hubble's high

247
00:10:42,490 --> 00:10:47,860
resolution allows us to look deeper into

248
00:10:45,159 --> 00:10:49,629
the core of globular clusters than any

249
00:10:47,860 --> 00:10:51,789
other telescopes its high resolution

250
00:10:49,629 --> 00:10:54,039
allows a more detailed studies of

251
00:10:51,789 --> 00:10:56,110
globular clusters closer into the center

252
00:10:54,039 --> 00:11:00,578
that's what Hubble provides for globular

253
00:10:56,110 --> 00:11:03,789
clusters and also in 1999 we got an

254
00:11:00,578 --> 00:11:05,708
image of the ring nebula now this is

255
00:11:03,789 --> 00:11:06,459
sort of the characteristic one of the

256
00:11:05,708 --> 00:11:09,279
10th

257

00:11:06,460 --> 00:11:11,019
ideas of a planetary nebula now

258
00:11:09,279 --> 00:11:13,539
planetary nebula is actually a misnomer

259
00:11:11,019 --> 00:11:16,059
it has nothing to do with planets what

260
00:11:13,539 --> 00:11:17,649
it really is is a dying star a star

261
00:11:16,059 --> 00:11:18,899
about the mass of the Sun are actually a

262
00:11:17,649 --> 00:11:21,519
little bit more massive than the Sun

263
00:11:18,899 --> 00:11:24,340
dies by blowing off its outer layers

264
00:11:21,519 --> 00:11:26,379
into space forming a gorgeous nebula

265
00:11:24,340 --> 00:11:27,970
that we call a planetary nebula and

266
00:11:26,379 --> 00:11:30,419
you've got the stellar remnant of the

267
00:11:27,970 --> 00:11:34,450
core and the beautiful gas around it and

268
00:11:30,419 --> 00:11:37,389
if I had to choose one set of images of

269
00:11:34,450 --> 00:11:40,000
one type of planetary object it would be

270
00:11:37,389 --> 00:11:42,639
planetary nebula because Hubble has 20

271
00:11:40,000 --> 00:11:45,690

or 30 gorgeous images of planetary

272

00:11:42,639 --> 00:11:50,679

nebula and this is prototypical of it

273

00:11:45,690 --> 00:11:53,680

well in December 1999 we had servicing

274

00:11:50,679 --> 00:11:56,019

mission 3a what had happened was that

275

00:11:53,679 --> 00:11:59,439

the gyroscopes on Hubble had failed

276

00:11:56,019 --> 00:12:01,269

Hubble could no longer point and we had

277

00:11:59,440 --> 00:12:03,160

to send up a servicing mission to

278

00:12:01,269 --> 00:12:05,860

restore Hubble to its scientific

279

00:12:03,159 --> 00:12:07,870

capabilities however servicing mission

280

00:12:05,860 --> 00:12:10,450

3a did not add any new imaging

281

00:12:07,870 --> 00:12:13,539

capabilities it just got Hubble back

282

00:12:10,450 --> 00:12:16,629

into doing scientific observations so in

283

00:12:13,539 --> 00:12:19,079

2001 released this image which you could

284

00:12:16,629 --> 00:12:22,860

definitely refer to as a Space Oddity

285

00:12:19,080 --> 00:12:25,270

this is an image of a gravitational lens

286
00:12:22,860 --> 00:12:28,810
what's going on here is this is the

287
00:12:25,269 --> 00:12:31,389
galaxy cluster Abell 22-18 and there are

288
00:12:28,809 --> 00:12:34,179
hundreds of thousands of galaxies here

289
00:12:31,389 --> 00:12:38,649
and the combined mass of all these

290
00:12:34,179 --> 00:12:41,409
galaxies warps space via Einstein's

291
00:12:38,649 --> 00:12:44,289
theory of general relativity mass warps

292
00:12:41,409 --> 00:12:47,199
space and this cluster has enough mass

293
00:12:44,289 --> 00:12:49,750
to warp the space such that the galaxies

294
00:12:47,200 --> 00:12:51,490
that are located beyond it as their

295
00:12:49,750 --> 00:12:54,580
light passes through this warp space

296
00:12:51,490 --> 00:12:56,740
their images become stretched out and

297
00:12:54,580 --> 00:12:59,770
these become these gravitationally

298
00:12:56,740 --> 00:13:04,389
lensed arcs that you see all across this

299
00:12:59,769 --> 00:13:06,009
image Hubble is a very important tool

300
00:13:04,389 --> 00:13:08,740
for studying gravitational lenses

301
00:13:06,009 --> 00:13:11,230
because it's high resolution can see

302
00:13:08,740 --> 00:13:15,549
these small thin and sometimes very

303
00:13:11,230 --> 00:13:18,700
faint gravitationally lensed arcs also

304
00:13:15,549 --> 00:13:20,608
in 2001 we had a another serendipitous

305
00:13:18,700 --> 00:13:24,908
event here in the solar system

306
00:13:20,609 --> 00:13:28,689
this is how Mars looked in June of 2001

307
00:13:24,908 --> 00:13:31,208
and you know it's a fine picture of Mars

308
00:13:28,688 --> 00:13:33,698
and Hubble is able to sort of monitor

309
00:13:31,208 --> 00:13:35,708
Mars and monitor the other planets and

310
00:13:33,698 --> 00:13:38,228
watch what happens on them and in

311
00:13:35,708 --> 00:13:41,168
September of 2001

312
00:13:38,229 --> 00:13:45,069
a dust storm that had started down in

313
00:13:41,168 --> 00:13:47,708
the Hellas Basin became global this is a

314

00:13:45,068 --> 00:13:50,498
global dust storm on Mars which we had

315
00:13:47,708 --> 00:13:52,838
seen at other times in Mars but Hubble

316
00:13:50,499 --> 00:13:55,359
from its perch above the atmosphere is

317
00:13:52,839 --> 00:13:57,429
able to get clear images of Mars and

318
00:13:55,359 --> 00:14:01,349
able to monitor it over the years and

319
00:13:57,428 --> 00:14:05,228
catch these events as they happen in

320
00:14:01,349 --> 00:14:06,999
2002 we had servicing mission 3b as I

321
00:14:05,229 --> 00:14:08,379
said servicing mission 3a was just the

322
00:14:06,999 --> 00:14:11,259
technical part of the servicing mission

323
00:14:08,379 --> 00:14:12,938
servicing mission 3b we put in a new

324
00:14:11,259 --> 00:14:15,639
camera called the advanced camera for

325
00:14:12,938 --> 00:14:18,338
surveys now wide field planetary camera

326
00:14:15,639 --> 00:14:21,219
2 that had been the workhorse camera on

327
00:14:18,339 --> 00:14:24,429
Hubble had a resolution of one tenth of

328
00:14:21,219 --> 00:14:27,220

an arc second and ACS has a resolution

329

00:14:24,428 --> 00:14:28,749

one twentieth of an arc second so we had

330

00:14:27,220 --> 00:14:32,499

twice the resolution with this new

331

00:14:28,749 --> 00:14:35,048

camera and it covered much larger has 16

332

00:14:32,499 --> 00:14:36,879

megapixels in the camera so we had a

333

00:14:35,048 --> 00:14:38,918

great increase in the imaging

334

00:14:36,879 --> 00:14:41,709

capabilities of Hubble after servicing

335

00:14:38,918 --> 00:14:44,708

mission 3b and one of the first images

336

00:14:41,708 --> 00:14:47,068

we released was this image of the

337

00:14:44,708 --> 00:14:49,598

interacting galaxies called the mice

338

00:14:47,068 --> 00:14:51,548

what you're seeing here are two galaxies

339

00:14:49,599 --> 00:14:53,499

that have come into each other's

340

00:14:51,548 --> 00:14:55,629

gravitational influence and have started

341

00:14:53,499 --> 00:14:57,339

to interact and created these big long

342

00:14:55,629 --> 00:14:59,558

tidal tails that stretch off this side

343
00:14:57,339 --> 00:15:02,139
and stretch off this side and the two

344
00:14:59,558 --> 00:15:04,629
cores of the galaxies here in the center

345
00:15:02,139 --> 00:15:07,298
these two galaxies will eventually merge

346
00:15:04,629 --> 00:15:09,339
together and Hubble will be able to see

347
00:15:07,298 --> 00:15:11,528
all the can see all the details deep

348
00:15:09,339 --> 00:15:16,689
down into the cores of these two merging

349
00:15:11,528 --> 00:15:19,359
galaxies in 2003 we got enough image of

350
00:15:16,688 --> 00:15:21,788
a more regular galaxy this is a

351
00:15:19,359 --> 00:15:24,879
lenticular galaxy called the sombrero

352
00:15:21,788 --> 00:15:26,438
galaxy and it has sort of a disc here

353
00:15:24,879 --> 00:15:28,959
that this characteristic of spiral

354
00:15:26,438 --> 00:15:31,658
galaxies but it also has this great big

355
00:15:28,958 --> 00:15:34,028
bulge of stars that's characteristic of

356
00:15:31,658 --> 00:15:34,419
elliptical galaxies those the two

357
00:15:34,028 --> 00:15:36,820
character

358
00:15:34,419 --> 00:15:39,370
Avalon ticular galaxy that it has the

359
00:15:36,820 --> 00:15:42,100
disk like a spiral and the bolt like an

360
00:15:39,370 --> 00:15:44,320
elliptical and what this image marks for

361
00:15:42,100 --> 00:15:46,839
me is really the movement towards

362
00:15:44,320 --> 00:15:48,820
getting large mosaics of Hubble images

363
00:15:46,839 --> 00:15:51,730
because although we're showing you about

364
00:15:48,820 --> 00:15:54,278
one megapixel here in total there's

365
00:15:51,730 --> 00:15:57,039
about 70 million pixels in this image

366
00:15:54,278 --> 00:15:59,169
this is several pointings of Hubble put

367
00:15:57,039 --> 00:16:01,360
together to create a large mosaic of

368
00:15:59,169 --> 00:16:05,789
this image and these would become much

369
00:16:01,360 --> 00:16:07,629
more prevalent as the years go on now in

370
00:16:05,789 --> 00:16:09,669
2004 we got one of the most

371

00:16:07,629 --> 00:16:11,429
scientifically significant images ever

372
00:16:09,669 --> 00:16:15,099
taken with the Hubble Space Telescope

373
00:16:11,429 --> 00:16:17,559
this is the Hubble Ultra Deep Field and

374
00:16:15,100 --> 00:16:19,930
in it you can see thousands upon

375
00:16:17,559 --> 00:16:22,388
thousands of galaxies there are a few

376
00:16:19,929 --> 00:16:24,489
stars you can see one here and one here

377
00:16:22,389 --> 00:16:26,980
they have the spikes the diffraction

378
00:16:24,490 --> 00:16:30,940
spikes on them but most everything you

379
00:16:26,980 --> 00:16:32,889
see in this image is a galaxy and well

380
00:16:30,940 --> 00:16:35,649
we've got the the big galaxies that look

381
00:16:32,889 --> 00:16:38,440
sort of like our normal galaxies but if

382
00:16:35,649 --> 00:16:41,078
we zoom into this image we can go in

383
00:16:38,440 --> 00:16:43,930
until we see go past all those big

384
00:16:41,078 --> 00:16:46,599
galaxies until we see these fine small

385
00:16:43,929 --> 00:16:49,059

galaxies and really what we want to end

386

00:16:46,600 --> 00:16:52,930

up looking at is a galaxy like this

387

00:16:49,059 --> 00:16:57,250

right here it's really just a small red

388

00:16:52,929 --> 00:17:00,179

dot this galaxy is about 10 or 11 or

389

00:16:57,250 --> 00:17:03,519

maybe even 12 billion light years away

390

00:17:00,179 --> 00:17:06,639

we're seeing galaxies all the way across

391

00:17:03,519 --> 00:17:09,189

the universe in this image and that's

392

00:17:06,640 --> 00:17:12,759

what makes the whole image so important

393

00:17:09,189 --> 00:17:15,308

that as we look at this image we're

394

00:17:12,759 --> 00:17:18,250

seeing galaxies throughout the universe

395

00:17:15,308 --> 00:17:22,088

out to ten to twelve billion light-years

396

00:17:18,250 --> 00:17:24,220

away from us and because they are 12

397

00:17:22,088 --> 00:17:26,139

billion light years away the light from

398

00:17:24,220 --> 00:17:28,690

those galaxies takes about 12 billion

399

00:17:26,140 --> 00:17:30,549

years to reach us so we're seeing these

400
00:17:28,690 --> 00:17:36,250
galaxies not as they are today

401
00:17:30,548 --> 00:17:38,589
but as they were 12 billion years ago we

402
00:17:36,250 --> 00:17:40,690
are seeing galaxies across the space of

403
00:17:38,589 --> 00:17:42,928
the universe but we're also seeing

404
00:17:40,690 --> 00:17:47,340
galaxies across the time of the universe

405
00:17:42,929 --> 00:17:52,440
this one image gives us a history of

406
00:17:47,339 --> 00:17:56,189
Alexei's throughout the universe in 2005

407
00:17:52,440 --> 00:17:58,140
we got what I gotta say is my favorite

408
00:17:56,190 --> 00:18:01,289
image of a galaxy that we've ever ever

409
00:17:58,140 --> 00:18:03,620
taken this is the Whirlpool Galaxy and

410
00:18:01,289 --> 00:18:06,930
it's a classic grand design spiral

411
00:18:03,619 --> 00:18:10,379
galaxy you see the wonderful spiral arms

412
00:18:06,930 --> 00:18:12,150
now again this is a mosaic image it

413
00:18:10,380 --> 00:18:13,890
contains about a hundred million pixels

414
00:18:12,150 --> 00:18:16,590
much more resolution than you can see on

415
00:18:13,890 --> 00:18:18,870
this monitor and every single one of

416
00:18:16,589 --> 00:18:21,509
these pink regions that dot the entire

417
00:18:18,869 --> 00:18:23,759
spiral structure of the galaxy is a star

418
00:18:21,509 --> 00:18:25,529
forming region and you have to recognize

419
00:18:23,759 --> 00:18:28,019
that all of these star forming regions

420
00:18:25,529 --> 00:18:30,000
have thousands to tens of thousands of

421
00:18:28,019 --> 00:18:31,799
stars that have formed in them and when

422
00:18:30,000 --> 00:18:34,200
you start to go in detail and see all of

423
00:18:31,799 --> 00:18:36,089
the star from regions across the spiral

424
00:18:34,200 --> 00:18:38,370
structure you can really start to

425
00:18:36,089 --> 00:18:41,699
comprehend that galaxies really are made

426
00:18:38,369 --> 00:18:44,339
up of hundreds of billions of stars I

427
00:18:41,700 --> 00:18:46,049
really love this image because it really

428

00:18:44,339 --> 00:18:49,039
shows you the structure of a spiral

429
00:18:46,049 --> 00:18:52,169
galaxy and it shows you the scale of

430
00:18:49,039 --> 00:18:54,000
galaxies out there in the universe of

431
00:18:52,170 --> 00:18:56,370
course we kept coming out with really

432
00:18:54,000 --> 00:18:59,670
other fantastic images and another one

433
00:18:56,369 --> 00:19:01,439
of my favorites is the Crab Nebula now

434
00:18:59,670 --> 00:19:03,120
previously we showed you a de Carina

435
00:19:01,440 --> 00:19:06,720
which was a star that's about to go

436
00:19:03,119 --> 00:19:09,000
explode well this is a star that has

437
00:19:06,720 --> 00:19:11,100
exploded this was a star that was

438
00:19:09,000 --> 00:19:13,859
observed about a thousand years ago to

439
00:19:11,099 --> 00:19:15,269
explode and this is the nebula created

440
00:19:13,859 --> 00:19:17,579
from the explosion when the car just

441
00:19:15,269 --> 00:19:20,099
basically blows its guts across space

442
00:19:17,579 --> 00:19:22,559

and this is a thousand years later as

443

00:19:20,099 --> 00:19:24,869

the remnants of the star have spread out

444

00:19:22,559 --> 00:19:26,700

across space and I got to say these

445

00:19:24,869 --> 00:19:29,879

remnants are moving at millions of miles

446

00:19:26,700 --> 00:19:33,240

an hour to create what we call the Crab

447

00:19:29,880 --> 00:19:35,610

Nebula and I gotta say the hits keep on

448

00:19:33,240 --> 00:19:37,160

coming at this time because the next

449

00:19:35,609 --> 00:19:39,689

image I have to show you is another

450

00:19:37,160 --> 00:19:42,990

fantastic image the image of the Orion

451

00:19:39,690 --> 00:19:45,360

Nebula this is our really large mosaic I

452

00:19:42,990 --> 00:19:48,150

think at full resolution we approach a

453

00:19:45,359 --> 00:19:49,979

billion pixels in this image and this is

454

00:19:48,150 --> 00:19:51,600

perhaps our most detailed and

455

00:19:49,980 --> 00:19:55,170

spectacular image of a star-forming

456

00:19:51,599 --> 00:19:58,319

region simply because the Orion Nebula

457
00:19:55,170 --> 00:20:01,110
is the nearest of the large star forming

458
00:19:58,319 --> 00:20:03,210
regions and so deep down in here we

459
00:20:01,109 --> 00:20:05,250
can see the stars that have just formed

460
00:20:03,210 --> 00:20:08,490
the stars in here are about two million

461
00:20:05,250 --> 00:20:10,230
years old we could also see the dust the

462
00:20:08,490 --> 00:20:12,240
disks of material around these newborn

463
00:20:10,230 --> 00:20:16,048
stars where planets will be forming we

464
00:20:12,240 --> 00:20:18,660
have an incredible view of how stars and

465
00:20:16,048 --> 00:20:23,970
planets form by studying this image of

466
00:20:18,660 --> 00:20:26,040
the Orion Nebula well in 2007 we got

467
00:20:23,970 --> 00:20:27,900
another gorgeous image of a star-forming

468
00:20:26,039 --> 00:20:30,058
region but this one's at a slightly

469
00:20:27,900 --> 00:20:31,798
different stage than the Orion Nebula in

470
00:20:30,058 --> 00:20:36,389
the Orion Nebula there was still

471
00:20:31,798 --> 00:20:38,759
surrounded by its gas in NGC 602 we have

472
00:20:36,390 --> 00:20:42,240
the star cluster here but it's already

473
00:20:38,759 --> 00:20:44,220
eaten away most of the nebula they form

474
00:20:42,240 --> 00:20:45,990
the pillars that you saw before in the

475
00:20:44,220 --> 00:20:49,829
Eagle Nebula you can see the pillars up

476
00:20:45,990 --> 00:20:53,039
here and down here that that created by

477
00:20:49,829 --> 00:20:57,329
the energy and the winds from these

478
00:20:53,039 --> 00:21:00,269
bright stars in this cluster now in 2008

479
00:20:57,329 --> 00:21:01,678
we had a opportunity to see something

480
00:21:00,269 --> 00:21:05,879
we've never seen before in the solar

481
00:21:01,679 --> 00:21:08,330
system we saw three red spots on Jupiter

482
00:21:05,880 --> 00:21:11,640
now we've seen the great red spot for

483
00:21:08,329 --> 00:21:13,019
continuously since about 1820 actually

484
00:21:11,640 --> 00:21:16,169
we might have even seen it as early as

485

00:21:13,019 --> 00:21:18,450
1670 but we're not quite sure early in

486
00:21:16,169 --> 00:21:21,000
the 2000s we saw the formation of red

487
00:21:18,450 --> 00:21:23,610
spot jr. and this is the first time

488
00:21:21,000 --> 00:21:27,690
we've ever seen a red spot form on the

489
00:21:23,609 --> 00:21:30,178
planet and in May of 2008 we saw the

490
00:21:27,690 --> 00:21:33,360
formation of what we call the baby red

491
00:21:30,179 --> 00:21:36,000
spot so first time in history we saw

492
00:21:33,359 --> 00:21:39,178
three red spots on the surface of

493
00:21:36,000 --> 00:21:41,339
Jupiter unfortunately this didn't happen

494
00:21:39,179 --> 00:21:44,340
this didn't last for very long because

495
00:21:41,339 --> 00:21:47,129
over the course of 2008 we followed it

496
00:21:44,339 --> 00:21:49,558
and you can see that baby red spot is on

497
00:21:47,130 --> 00:21:51,720
the same latitude as the great red spot

498
00:21:49,558 --> 00:21:54,149
and over the course of that summer

499
00:21:51,720 --> 00:21:56,970

interacted with it and eventually broke

500

00:21:54,150 --> 00:21:59,730

up and no longer was a red spot at the

501

00:21:56,970 --> 00:22:02,730

end so Hubble was able to follow the

502

00:21:59,730 --> 00:22:06,839

formation and ultimately the destruction

503

00:22:02,730 --> 00:22:09,509

of the baby Red Spot on Jupiter well in

504

00:22:06,839 --> 00:22:10,709

2009 Servicing mission for finally

505

00:22:09,509 --> 00:22:13,140

happened this was something that was

506

00:22:10,710 --> 00:22:14,579

scheduled for several years earlier but

507

00:22:13,140 --> 00:22:15,570

due to this

508

00:22:14,579 --> 00:22:18,599

accident of the space shuttle Columbia

509

00:22:15,569 --> 00:22:21,509

was delayed for several years but in May

510

00:22:18,599 --> 00:22:23,849

2009 we have this image of astronaut

511

00:22:21,509 --> 00:22:28,200

drew boy still working on his very first

512

00:22:23,849 --> 00:22:30,569

spacewalk and in during the during

513

00:22:28,200 --> 00:22:32,100

servicing mission for we installed two

514
00:22:30,569 --> 00:22:35,519
brand new instruments Wide Field Camera

515
00:22:32,099 --> 00:22:38,879
3 and the cosmic origins spectrograph to

516
00:22:35,519 --> 00:22:40,829
add to Hubble's capabilities the early

517
00:22:38,880 --> 00:22:43,560
riess observations were absolutely

518
00:22:40,829 --> 00:22:45,389
spectacular this was one of the first

519
00:22:43,559 --> 00:22:48,389
early Rees observations a planetary

520
00:22:45,390 --> 00:22:49,980
nebula called the bug nebula although in

521
00:22:48,390 --> 00:22:51,930
our press release we refer to it as the

522
00:22:49,980 --> 00:22:54,059
butterfly nebula and that name seems to

523
00:22:51,930 --> 00:22:55,769
a stick it really does fit because it

524
00:22:54,059 --> 00:22:57,779
does look like a butterfly these are

525
00:22:55,769 --> 00:23:00,119
actually hourglass shape lobes of

526
00:22:57,779 --> 00:23:03,420
material streaming away from the dying

527
00:23:00,119 --> 00:23:05,369
star at its center absolutely gorgeous

528
00:23:03,420 --> 00:23:08,250
shows that Hubble is back in business

529
00:23:05,369 --> 00:23:10,019
but this image also from the

530
00:23:08,250 --> 00:23:12,750
early-release observations of the

531
00:23:10,019 --> 00:23:15,480
central regions of omega centauri shows

532
00:23:12,750 --> 00:23:18,240
off the new capabilities this is a

533
00:23:15,480 --> 00:23:20,279
combined infrared and ultraviolet image

534
00:23:18,240 --> 00:23:23,220
there's actually no visible light in

535
00:23:20,279 --> 00:23:25,529
this image the red stars are the stars

536
00:23:23,220 --> 00:23:27,569
that shine bright in infrared and the

537
00:23:25,529 --> 00:23:30,029
blue stars of the stars that shine

538
00:23:27,569 --> 00:23:31,769
bright in the ultraviolet and we can

539
00:23:30,029 --> 00:23:34,829
pick out sort of the extremes of

540
00:23:31,769 --> 00:23:37,519
temperatures within omega sin with our

541
00:23:34,829 --> 00:23:42,419
new capabilities of Wide Field Camera 3

542

00:23:37,519 --> 00:23:45,329
so that is 19 years of hull imagery and

543
00:23:42,420 --> 00:23:47,430
for the 20th anniversary we had to come

544
00:23:45,329 --> 00:23:48,899
up with something spectacular we had to

545
00:23:47,430 --> 00:23:51,120
say all right how are we really gonna

546
00:23:48,900 --> 00:23:52,980
celebrate this but we've got so much

547
00:23:51,119 --> 00:23:55,609
gorgeous imagery could we really come up

548
00:23:52,980 --> 00:23:59,910
with something really spectacular I

549
00:23:55,609 --> 00:24:03,000
happen to think that yes he did this is

550
00:23:59,910 --> 00:24:06,660
our 20th anniversary image a pillar in

551
00:24:03,000 --> 00:24:09,630
the Carina Nebula now this is like the

552
00:24:06,660 --> 00:24:11,670
pillar in eel nebula in that the pillars

553
00:24:09,630 --> 00:24:13,830
are being carved out by those

554
00:24:11,670 --> 00:24:16,560
high-energy radiation and winds from

555
00:24:13,829 --> 00:24:20,699
bright stars but it's absolutely a

556
00:24:16,559 --> 00:24:24,480

gorgeous gorgeous view of a pillar in

557

00:24:20,700 --> 00:24:26,509

Carina and it includes at the top of

558

00:24:24,480 --> 00:24:28,259

this pillar and the top of this pillar

559

00:24:26,509 --> 00:24:31,529

jets from Nouveau

560

00:24:28,259 --> 00:24:33,390

stars when stars first turn on they send

561

00:24:31,529 --> 00:24:35,670

out these oppositely directed Jets that

562

00:24:33,390 --> 00:24:37,770

spew out and announce their birth where

563

00:24:35,670 --> 00:24:39,870

you can see them a star has just formed

564

00:24:37,769 --> 00:24:42,180

the top of this pillar and one that has

565

00:24:39,869 --> 00:24:45,539

formed at the top of this pillar this is

566

00:24:42,180 --> 00:24:47,370

an incredible image and having learned

567

00:24:45,539 --> 00:24:50,190

what we did in creating the imax film

568

00:24:47,369 --> 00:24:55,169

Hubble 3d we were able to put this one

569

00:24:50,190 --> 00:24:57,120

into 3d motion this in this animation

570

00:24:55,170 --> 00:24:59,100

what we've done is we've taken the

571
00:24:57,119 --> 00:25:01,109
pillars and Carina Nebula we've

572
00:24:59,099 --> 00:25:03,869
separated out layers of stars we've

573
00:25:01,109 --> 00:25:06,809
separated out layers of the pillar and

574
00:25:03,869 --> 00:25:09,509
we have pulled them into a 3d program

575
00:25:06,809 --> 00:25:12,509
and allowed us to fly through it in 3d

576
00:25:09,509 --> 00:25:14,640
to give you a sort of 3d feel now this

577
00:25:12,509 --> 00:25:17,129
is not scientifically accurate but it

578
00:25:14,640 --> 00:25:19,759
gives you a 3d feel for the structure of

579
00:25:17,130 --> 00:25:19,760
the nebula

580
00:25:23,880 --> 00:25:30,750
so that's it that's 20 images for 20

581
00:25:27,808 --> 00:25:33,720
years of Hubble now 20 images is

582
00:25:30,750 --> 00:25:36,150
relatively small because Hubble has

583
00:25:33,720 --> 00:25:38,160
actually released of over a thousand

584
00:25:36,150 --> 00:25:40,410
public release images it's taken nearly

585
00:25:38,160 --> 00:25:43,200
a million observations we have released

586
00:25:40,410 --> 00:25:46,230
over a thousand public release images

587
00:25:43,200 --> 00:25:48,900
and here is April almost mind-boggling

588
00:25:46,230 --> 00:25:50,849
montage of Hubble images so if I didn't

589
00:25:48,900 --> 00:25:54,538
cover your favorite one perhaps you can

590
00:25:50,849 --> 00:25:57,329
see it in this montage I'd like to

591
00:25:54,538 --> 00:25:59,640
finish with one last image this is a

592
00:25:57,329 --> 00:26:02,428
sort of poetic image of Hubble hanging

593
00:25:59,640 --> 00:26:04,140
over the limb of Earth but this this

594
00:26:02,429 --> 00:26:06,509
image has even a little bit more meaning

595
00:26:04,140 --> 00:26:09,150
to us because this is the last image

596
00:26:06,509 --> 00:26:11,369
from servicing mission 4 and servicing

597
00:26:09,150 --> 00:26:12,900
mission 4 is the last shuttle mission to

598
00:26:11,369 --> 00:26:15,538
Hubble simply because the shuttle

599

00:26:12,900 --> 00:26:18,780
program is ending so this is sort of the

600
00:26:15,538 --> 00:26:21,419
the last view that humans had of the

601
00:26:18,779 --> 00:26:23,609
Hubble Space Telescope now you can see

602
00:26:21,419 --> 00:26:27,059
that Hubble is really just above Earth's

603
00:26:23,609 --> 00:26:28,469
atmosphere and as an astronomer early on

604
00:26:27,058 --> 00:26:30,509
I thought that putting Hubble in

605
00:26:28,470 --> 00:26:32,100
low-earth orbit was a problem because

606
00:26:30,509 --> 00:26:35,038
you've got the earth there you've got

607
00:26:32,099 --> 00:26:37,529
the Van Allen belts radiation around it

608
00:26:35,038 --> 00:26:39,179
you're going from day to night every 90

609
00:26:37,529 --> 00:26:41,329
minutes it really causes a lot of

610
00:26:39,179 --> 00:26:44,940
problems for astronomical observations

611
00:26:41,329 --> 00:26:47,099
however having Hubble in low-earth orbit

612
00:26:44,940 --> 00:26:50,490
and being able to send shuttle missions

613
00:26:47,099 --> 00:26:53,908

up to repair it has enabled Hubble to

614

00:26:50,490 --> 00:26:56,250

stay current we are able to take out the

615

00:26:53,909 --> 00:26:59,220

old instruments and put in new

616

00:26:56,250 --> 00:27:02,429

technology which keeps Hubble current

617

00:26:59,220 --> 00:27:04,669

one I mean you've seen the changes in

618

00:27:02,429 --> 00:27:07,980

this episode of the Hubble observations

619

00:27:04,669 --> 00:27:11,100

but it also provides changes in what

620

00:27:07,980 --> 00:27:13,349

Hubble can study Hubble has made

621

00:27:11,099 --> 00:27:17,279

significant contributions to the study

622

00:27:13,349 --> 00:27:19,469

of dark energy when we had no idea that

623

00:27:17,279 --> 00:27:21,509

that scientific problem was even going

624

00:27:19,470 --> 00:27:24,659

to be around woodhull was on the drawing

625

00:27:21,509 --> 00:27:27,058

board changing out the instruments has

626

00:27:24,659 --> 00:27:29,400

enabled Howell to not only increase its

627

00:27:27,058 --> 00:27:31,579

vision of the universe but also to

628
00:27:29,400 --> 00:27:34,440
increase the number of scientific

629
00:27:31,579 --> 00:27:36,658
capable scientific questions that Hubble

630
00:27:34,440 --> 00:27:37,680
can answer and that is one of its

631
00:27:36,659 --> 00:27:40,710
legacies

632
00:27:37,680 --> 00:27:44,250
an orbiting observatory can change and

633
00:27:40,710 --> 00:27:47,730
adapt and address brand new problems

634
00:27:44,250 --> 00:27:49,069
over its 20 years and of course Hubble

635
00:27:47,730 --> 00:27:51,539
is not finished yet

636
00:27:49,069 --> 00:27:53,879
after servicing mission 4 is in

637
00:27:51,539 --> 00:27:55,049
wonderful condition we expect it to last

638
00:27:53,880 --> 00:27:57,690
for another 10 years

639
00:27:55,049 --> 00:27:59,909
who knows maybe more and how we'll be

640
00:27:57,690 --> 00:28:02,490
able to lure a lot more beautiful images

641
00:27:59,910 --> 00:28:03,560
and a lot more cutting-edge science for

642
00:28:02,490 --> 00:28:06,089
years to come

643
00:28:03,559 --> 00:28:07,619
thank you for joining us we'll see you

644
00:28:06,089 --> 00:28:09,549
next time on Hubble's universe

645
00:28:07,619 --> 00:28:13,209
unfiltered

646
00:28:09,549 --> 00:28:13,210
[Music]