1
00:00:00,590 --> 00:00:15,670
[Music]

2
00:00:20,179 --> 00:00:18,710
hi I'm dr. Frank summers of the Space

3
00:00:22,519 --> 00:00:20,189
Telescope Science Institute

4
00:00:25,490 --> 00:00:22,529
welcome to Hubble's universe unfiltered

5
00:00:26,089 --> 00:00:25,500
or perhaps I should be saying welcome

6
00:00:27,920 --> 00:00:26,099
back

7
00:00:30,230 --> 00:00:27,930
we've been on hatest for several months

8
00:00:32,510 --> 00:00:30,240
but there's a really good reason why

9
00:00:36,740 --> 00:00:32,520
we're on hiatus we were working on the

10
00:00:37,639 --> 00:00:36,750
IMAX film Hubble 3d myself and gentlemen

11
00:00:39,799 --> 00:00:37,649
behind the camera

12
00:00:42,979 --> 00:00:39,809
we're heavily involved in creating the

13
00:00:46,270 --> 00:00:42,989

sequences of Hubble imagery in 3d for

14
00:00:49,700 --> 00:00:46,280
that film the film came out in March of

15
00:00:51,950 --> 00:00:49,710
2010 and our work on that film will be

16
00:00:54,799 --> 00:00:51,960
the subject of some upcoming episodes of

17
00:00:56,959 --> 00:00:54,809
Hubble's universe unfiltered for today's

18
00:00:58,819 --> 00:00:56,969
episode I'd like to talk about another

19
00:01:02,270 --> 00:00:58,829
special event that we had this spring

20
00:01:06,410 --> 00:01:02,280
Hubble's 20th anniversary this image

21
00:01:08,359 --> 00:01:06,420
shows you April 24th 1990 the launch of

22
00:01:12,200 --> 00:01:08,369
the space shuttle Discovery carrying

23
00:01:15,200 --> 00:01:12,210
Hubble a lot into space and on this

24
00:01:17,480 --> 00:01:15,210
service shuttle mission put Hubble into

25
00:01:19,850 --> 00:01:17,490
orbit into its platform from which it

26
00:01:22,640 --> 00:01:19,860
observes the universe it has been up for

27
00:01:25,130 --> 00:01:22,650
20 years now taking an incredible number

28
00:01:27,890 --> 00:01:25,140
of observations so how does one

29
00:01:31,340 --> 00:01:27,900
celebrate 20 years of such an amazing

30
00:01:34,789 --> 00:01:31,350
telescope well I was asked to come up

31
00:01:36,410 --> 00:01:34,799
with 20 images to sort of show the

32
00:01:40,359 --> 00:01:36,420
breadth and depth of what Hubble has

33
00:01:43,249 --> 00:01:40,369
done over over its observing history and

34
00:01:44,960 --> 00:01:43,259
the first idea was to come up with all

35
00:01:47,870 --> 00:01:44,970
the most scientific interesting images

36
00:01:49,789 --> 00:01:47,880
well the most scientifically significant

37
00:01:52,190 --> 00:01:49,799
images oftentimes aren't the most

38
00:01:54,740 --> 00:01:52,200

beautiful images and it often takes an

39
00:01:56,660 --> 00:01:54,750
entire episode of this video podcast in

40
00:01:59,539 --> 00:01:56,670
order to explain why these images are so

41
00:02:02,359 --> 00:01:59,549
significant the other idea would be then

42
00:02:04,459 --> 00:02:02,369
to go for the most beautiful images well

43
00:02:06,020 --> 00:02:04,469
then you tend to look only at the later

44
00:02:08,119 --> 00:02:06,030
part of Hubble's life when we had the

45
00:02:09,919 --> 00:02:08,129
newer instruments on Hubble and you sort

46
00:02:12,619 --> 00:02:09,929
of ignore the early parts of Hubble's

47
00:02:13,080 --> 00:02:12,629
observations so what we ended up coming

48
00:02:15,570 --> 00:02:13,090
up

49
00:02:18,809 --> 00:02:15,580
is sort of a combination of those images

50
00:02:21,540 --> 00:02:18,819
that cover the full 20 years of Hubble

51
00:02:23,339 --> 00:02:21,550
that cover all of the different subjects

52
00:02:27,180 --> 00:02:23,349
that Hubble has looked at from planets

53
00:02:29,820 --> 00:02:27,190
to stars to nebulae to galaxies and one

54
00:02:31,380 --> 00:02:29,830
that sort of covers the breadth of how

55
00:02:34,470 --> 00:02:31,390
much we've done in terms of science and

56
00:02:36,360 --> 00:02:34,480
significance as well as beauty now

57
00:02:38,699 --> 00:02:36,370
there's something that I had to get out

58
00:02:40,740 --> 00:02:38,709
of the way right away is that after

59
00:02:42,570 --> 00:02:40,750
Hubble was put into orbit there was the

60
00:02:44,759 --> 00:02:42,580
flaw on the mirror and it's sort of a

61
00:02:46,620 --> 00:02:44,769
mythos that Hubble was unusable for the

62
00:02:49,979 --> 00:02:46,630
first few years until that flaw was

63
00:02:52,710 --> 00:02:49,989

corrected that's not true and you can

64
00:02:55,410 --> 00:02:52,720
see in this image of a double star that

65
00:02:58,740 --> 00:02:55,420
Hubble did provide advantages during its

66
00:03:00,750 --> 00:02:58,750
first few years on this side you see a

67
00:03:03,420 --> 00:03:00,760
double star as observed from the ground

68
00:03:05,460 --> 00:03:03,430
and you can see here that it's really

69
00:03:06,300 --> 00:03:05,470
just one blob and the two stars are

70
00:03:09,000 --> 00:03:06,310
merged together

71
00:03:10,860 --> 00:03:09,010
that's because from the ground we have

72
00:03:12,630 --> 00:03:10,870
the atmosphere in between us which

73
00:03:13,470 --> 00:03:12,640
limits our resolution to about one

74
00:03:16,020 --> 00:03:13,480
arcsecond

75
00:03:18,150 --> 00:03:16,030
on the other side we have Hubble's

76
00:03:20,250 --> 00:03:18,160
observation of the exact same double

77
00:03:22,170 --> 00:03:20,260
star and you can see that although the

78
00:03:24,300 --> 00:03:22,180
stars aren't the perfect little

79
00:03:27,750 --> 00:03:24,310
pinpoints we want them to be you can

80
00:03:29,640 --> 00:03:27,760
resolve the two stars even with the flaw

81
00:03:32,610 --> 00:03:29,650
on the mirror Hubble had finer

82
00:03:35,069 --> 00:03:32,620
resolution than any telescope from the

83
00:03:36,539 --> 00:03:35,079
ground so Hubble was able to do good

84
00:03:39,479 --> 00:03:36,549
science for the first three years before

85
00:03:42,960 --> 00:03:39,489
it was repaired and as one example from

86
00:03:47,009 --> 00:03:42,970
1992 is this image of the galaxy Messier

87
00:03:49,410 --> 00:03:47,019
87 now Messier 87 is a giant optical

88
00:03:51,240 --> 00:03:49,420

galaxy contains you know hundreds of

89
00:03:54,750 --> 00:03:51,250
billions of stars maybe even a trillion

90
00:03:57,420 --> 00:03:54,760
stars and at its core is a very bright

91
00:04:00,930 --> 00:03:57,430
source that we believe to be a super

92
00:04:03,840 --> 00:04:00,940
massive black hole this is a matte black

93
00:04:06,030 --> 00:04:03,850
hole with many perhaps even a billion

94
00:04:09,420 --> 00:04:06,040
solar masses a billion times the mass of

95
00:04:11,370 --> 00:04:09,430
our Sun in a black hole and with all the

96
00:04:13,020 --> 00:04:11,380
materials swirling around it and all the

97
00:04:16,199 --> 00:04:13,030
energy of that supermassive black hole

98
00:04:18,420 --> 00:04:16,209
it is spewing out this incredibly jet of

99
00:04:21,000 --> 00:04:18,430
radiation from that supermassive black

100
00:04:24,060 --> 00:04:21,010
hole and Hubble was able to take a

101
00:04:26,580 --> 00:04:24,070
highly resolved view of that super matte

102
00:04:31,770 --> 00:04:26,590
of that jet in galaxies

103
00:04:33,990 --> 00:04:31,780
Messier 87 well in 1993 we did have

104
00:04:36,480 --> 00:04:34,000
servicing mission one and the astronauts

105
00:04:38,640 --> 00:04:36,490
went up and this picture is of them

106
00:04:40,350 --> 00:04:38,650
either taking out Wide Field Camera one

107
00:04:42,960 --> 00:04:40,360
or putting in wide field planetary

108
00:04:44,640 --> 00:04:42,970
camera - that's kind of hard to tell

109
00:04:48,420 --> 00:04:44,650
because they look pretty much exactly

110
00:04:50,850 --> 00:04:48,430
alike wide field planetary camera - had

111
00:04:52,469 --> 00:04:50,860
the correction for the flaw in the

112
00:04:55,170 --> 00:04:52,479
mirror already built into it the

113
00:04:57,090 --> 00:04:55,180

astronauts also put in an instrument

114
00:04:59,040 --> 00:04:57,100
called co-star which had basically

115
00:05:02,190 --> 00:04:59,050
eyeglasses for the other instruments and

116
00:05:05,370 --> 00:05:02,200
that gave Hubble back the resolution was

117
00:05:07,020 --> 00:05:05,380
supposed to have so this next image is I

118
00:05:10,830 --> 00:05:07,030
sometimes jokingly call the most

119
00:05:13,260 --> 00:05:10,840
important Hubble image ever because this

120
00:05:16,170 --> 00:05:13,270
shows you that the repair was successful

121
00:05:18,600 --> 00:05:16,180
on this side we see an image from wide

122
00:05:21,659 --> 00:05:18,610
field planetary camera one of the core

123
00:05:24,060 --> 00:05:21,669
of the galaxy Messier 100 and you can

124
00:05:27,629 --> 00:05:24,070
see the structure in there but you can't

125
00:05:29,100 --> 00:05:27,639
see all the fine details on this side we

126
00:05:31,770 --> 00:05:29,110
see the image from wide field planetary

127
00:05:34,500 --> 00:05:31,780
camera - which had the correction and

128
00:05:37,740 --> 00:05:34,510
you can see voila all of the incredible

129
00:05:39,420 --> 00:05:37,750
details this is the fine detail for

130
00:05:42,480 --> 00:05:39,430
which the Hubble images are really known

131
00:05:44,550 --> 00:05:42,490
and sort of crispness that characterizes

132
00:05:48,089 --> 00:05:44,560
all the Hubble images you've seen over

133
00:05:50,310 --> 00:05:48,099
the decades so this image really said to

134
00:05:51,900 --> 00:05:50,320
the astronomical community yes

135
00:05:54,390 --> 00:05:51,910
Hubble is achieving its design

136
00:05:56,010 --> 00:05:54,400
specifications and from there on it was

137
00:05:59,010 --> 00:05:56,020
able to do the science that we

138
00:06:02,490 --> 00:05:59,020

originally hoped it would do so here

139
00:06:05,000 --> 00:06:02,500
come a slew of images but actually there

140
00:06:09,029 --> 00:06:05,010
was a wonderful case of serendipity in

141
00:06:11,370 --> 00:06:09,039
1994 because in 1993 comet

142
00:06:14,219 --> 00:06:11,380
shoemaker-levy 9 went into orbit around

143
00:06:17,129 --> 00:06:14,229
Jupiter and it broke up into 20 or 30

144
00:06:21,270 --> 00:06:17,139
pieces and it was calculated to hit

145
00:06:23,219 --> 00:06:21,280
Jupiter in July of 1994 it was a very

146
00:06:24,750 --> 00:06:23,229
nice comment because it waited until

147
00:06:27,650 --> 00:06:24,760
Hubble had been repaired

148
00:06:30,750 --> 00:06:27,660
so that Hubble could take gorgeous and

149
00:06:33,240 --> 00:06:30,760
highly detailed images of impact sites

150
00:06:35,790 --> 00:06:33,250
you see those impact sites here in the

151
00:06:37,830 --> 00:06:35,800
lower part of Jupiter and in visible

152
00:06:40,050 --> 00:06:37,840
light they show up as basically big

153
00:06:44,290 --> 00:06:40,060
brown clouds in its atmosphere

154
00:06:46,450 --> 00:06:44,300
in ultraviolet light on this side you

155
00:06:48,550 --> 00:06:46,460
can see that the holes in Jupiter's

156
00:06:52,390 --> 00:06:48,560
atmosphere are actually much larger and

157
00:06:55,240 --> 00:06:52,400
it's important that ultraviolet light is

158
00:06:56,710 --> 00:06:55,250
not viewable from the ground I know you

159
00:06:58,810 --> 00:06:56,720
think you get lots of ultraviolet light

160
00:07:00,610 --> 00:06:58,820
when you get suntan most of the

161
00:07:02,920 --> 00:07:00,620
ultraviolet light is absorbed by Earth's

162
00:07:05,110 --> 00:07:02,930
atmosphere so to do astronomical

163
00:07:07,840 --> 00:07:05,120

observations of ultraviolet light you

164
00:07:09,880 --> 00:07:07,850
must get up into space and Hubble's

165
00:07:12,400 --> 00:07:09,890
platform in space allowed it to view

166
00:07:14,890 --> 00:07:12,410
these impact site in ultraviolet and see

167
00:07:16,630 --> 00:07:14,900
the real detail by the way this is not

168
00:07:18,820 --> 00:07:16,640
an impact site this is just the shadow

169
00:07:20,460 --> 00:07:18,830
of one of Jupiter's moons going across

170
00:07:25,330 --> 00:07:20,470
the surface of Jupiter

171
00:07:27,580 --> 00:07:25,340
well 1995 was a watershed image that

172
00:07:29,740 --> 00:07:27,590
came out called the pillars in the Eagle

173
00:07:32,350 --> 00:07:29,750
Nebula some people call this the pillars

174
00:07:34,690 --> 00:07:32,360
of creation and what's going on here is

175
00:07:37,000 --> 00:07:34,700
that there is dense gas inside these

176
00:07:38,620 --> 00:07:37,010
pillars that is being illuminated by

177
00:07:40,690 --> 00:07:38,630
some bright stars that are up here

178
00:07:43,060 --> 00:07:40,700
matter of fact the high-energy radiation

179
00:07:44,920 --> 00:07:43,070
from those bright stars and winds from

180
00:07:47,170 --> 00:07:44,930
those stars are sweeping across this

181
00:07:50,050 --> 00:07:47,180
region blowing away all the low-density

182
00:07:53,710 --> 00:07:50,060
gas leaving the high-density gas in

183
00:07:56,740 --> 00:07:53,720
these pillars and this gas is such high

184
00:07:58,150 --> 00:07:56,750
density that stars are forming and you

185
00:08:00,010 --> 00:07:58,160
can see at the top of this tallest

186
00:08:03,190 --> 00:08:00,020
pillar that there are little fingers

187
00:08:06,640 --> 00:08:03,200
here and that is where individual stars

188
00:08:09,040 --> 00:08:06,650

are forming this image really you know

189
00:08:11,770 --> 00:08:09,050
captured people's imagination and is

190
00:08:16,300 --> 00:08:11,780
perhaps the most famous of all of the

191
00:08:19,660 --> 00:08:16,310
Hubble images 1996 we captured this

192
00:08:23,080 --> 00:08:19,670
amazing image this is of the dying star

193
00:08:25,480 --> 00:08:23,090
a de Carina now the star is deeply

194
00:08:28,390 --> 00:08:25,490
embedded in here and what you see more

195
00:08:30,700 --> 00:08:28,400
is the lobes of gas that have been blown

196
00:08:33,159 --> 00:08:30,710
out from the star during its death

197
00:08:36,339 --> 00:08:33,169
throes this star is believed to be a

198
00:08:40,210 --> 00:08:36,349
hundred to 150 times the mass of our Sun

199
00:08:43,210 --> 00:08:40,220
and sometime in the next million to ten

200
00:08:45,820 --> 00:08:43,220
million years we expect this star will

201
00:08:49,240 --> 00:08:45,830
explode it will go as a supernova and to

202
00:08:52,810 --> 00:08:49,250
basically blow its guts across space so

203
00:08:53,810 --> 00:08:52,820
this is a star in its preliminary depth

204
00:08:58,560 --> 00:08:53,820
for

205
00:09:01,019 --> 00:08:58,570
well 1997 was the year of our second

206
00:09:03,090 --> 00:09:01,029
servicing mission to Hubble and in terms

207
00:09:05,100 --> 00:09:03,100
of imaging we put in two brand-new

208
00:09:07,290 --> 00:09:05,110
instruments the near infrared camera

209
00:09:09,000 --> 00:09:07,300
multi-object spectrograph which we

210
00:09:11,490 --> 00:09:09,010
usually just call Nick Moss that was an

211
00:09:13,829 --> 00:09:11,500
infrared camera and the Space Telescope

212
00:09:17,519 --> 00:09:13,839
imaging spectrograph which we usually

213
00:09:19,650 --> 00:09:17,529

call stiffs which had both ultraviolet

214
00:09:22,550 --> 00:09:19,660
and visible-light coverage but was

215
00:09:25,410 --> 00:09:22,560
especially sensitive in the ultraviolet

216
00:09:27,960 --> 00:09:25,420
that ultraviolet capability showed up

217
00:09:30,840 --> 00:09:27,970
the next year in this image of Saturn

218
00:09:33,810 --> 00:09:30,850
this is an ultraviolet image of Saturn

219
00:09:36,480 --> 00:09:33,820
and in particular of the Aurora on

220
00:09:38,639 --> 00:09:36,490
Saturn now you got to recognize that

221
00:09:41,819 --> 00:09:38,649
Saturn is about ten times farther away

222
00:09:45,329 --> 00:09:41,829
from the Sun than Earth is and so the

223
00:09:48,960 --> 00:09:45,339
solar wind is expected to be about 1/100

224
00:09:50,340 --> 00:09:48,970
the density it is at earth so we did not

225
00:09:53,730 --> 00:09:50,350
expect that the solar wind will be

226
00:09:56,400 --> 00:09:53,740
strong enough to produce a lot of Aurora

227
00:09:59,100 --> 00:09:56,410
on Saturn however when we look at these

228
00:10:01,079 --> 00:09:59,110
images the power in Saturn's Aurora as

229
00:10:04,170 --> 00:10:01,089
well as the changes in Saturn's roar

230
00:10:06,569 --> 00:10:04,180
surprised us as astronomers and using

231
00:10:11,460 --> 00:10:06,579
ultraviolet capabilities of Hubble we're

232
00:10:13,460 --> 00:10:11,470
able to study that in 1999 we got this

233
00:10:16,230 --> 00:10:13,470
wonderful image of a globular cluster

234
00:10:18,590 --> 00:10:16,240
now a globular cluster is a dense

235
00:10:22,530 --> 00:10:18,600
collection of stars this one has about

236
00:10:24,840 --> 00:10:22,540
50,000 stars its name is Messier 80 and

237
00:10:27,810 --> 00:10:24,850
all of these stars are orbiting around

238
00:10:29,100 --> 00:10:27,820

one another it's important to have high

239
00:10:31,620 --> 00:10:29,110
resolution when you are studying

240
00:10:33,150 --> 00:10:31,630
globular clusters because you see at the

241
00:10:35,550 --> 00:10:33,160
center of this image it sort of blown

242
00:10:36,689 --> 00:10:35,560
out it's all white you can't make out

243
00:10:38,759 --> 00:10:36,699
individual stars

244
00:10:40,139 --> 00:10:38,769
well that's true in all globular

245
00:10:42,480 --> 00:10:40,149
clusters that they're all very dense

246
00:10:45,150 --> 00:10:42,490
than the core and Hubble's high

247
00:10:47,850 --> 00:10:45,160
resolution allows us to look deeper into

248
00:10:49,620 --> 00:10:47,860
the core of globular clusters than any

249
00:10:51,780 --> 00:10:49,630
other telescopes its high resolution

250
00:10:54,030 --> 00:10:51,790
allows a more detailed studies of

251
00:10:56,100 --> 00:10:54,040
globular clusters closer into the center

252
00:11:00,569 --> 00:10:56,110
that's what Hubble provides for globular

253
00:11:03,780 --> 00:11:00,579
clusters and also in 1999 we got an

254
00:11:05,699 --> 00:11:03,790
image of the ring nebula now this is

255
00:11:06,450 --> 00:11:05,709
sort of the characteristic one of the

256
00:11:09,270 --> 00:11:06,460
10th

257
00:11:11,010 --> 00:11:09,280
ideas of a planetary nebula now

258
00:11:13,530 --> 00:11:11,020
planetary nebula is actually a misnomer

259
00:11:16,050 --> 00:11:13,540
it has nothing to do with planets what

260
00:11:17,640 --> 00:11:16,060
it really is is a dying star a star

261
00:11:18,890 --> 00:11:17,650
about the mass of the Sun are actually a

262
00:11:21,510 --> 00:11:18,900
little bit more massive than the Sun

263
00:11:24,330 --> 00:11:21,520

dies by blowing off its outer layers

264
00:11:26,370 --> 00:11:24,340
into space forming a gorgeous nebula

265
00:11:27,960 --> 00:11:26,380
that we call a planetary nebula and

266
00:11:30,410 --> 00:11:27,970
you've got the stellar remnant of the

267
00:11:34,440 --> 00:11:30,420
core and the beautiful gas around it and

268
00:11:37,380 --> 00:11:34,450
if I had to choose one set of images of

269
00:11:39,990 --> 00:11:37,390
one type of planetary object it would be

270
00:11:42,630 --> 00:11:40,000
planetary nebula because Hubble has 20

271
00:11:45,680 --> 00:11:42,640
or 30 gorgeous images of planetary

272
00:11:50,670 --> 00:11:45,690
nebula and this is prototypical of it

273
00:11:53,670 --> 00:11:50,680
well in December 1999 we had servicing

274
00:11:56,010 --> 00:11:53,680
mission 3a what had happened was that

275
00:11:59,430 --> 00:11:56,020
the gyroscopes on Hubble had failed

276
00:12:01,260 --> 00:11:59,440
Hubble could no longer point and we had

277
00:12:03,150 --> 00:12:01,270
to send up a servicing mission to

278
00:12:05,850 --> 00:12:03,160
restore Hubble to its scientific

279
00:12:07,860 --> 00:12:05,860
capabilities however servicing mission

280
00:12:10,440 --> 00:12:07,870
3a did not add any new imaging

281
00:12:13,530 --> 00:12:10,450
capabilities it just got Hubble back

282
00:12:16,620 --> 00:12:13,540
into doing scientific observations so in

283
00:12:19,070 --> 00:12:16,630
2001 released this image which you could

284
00:12:22,850 --> 00:12:19,080
definitely refer to as a Space Oddity

285
00:12:25,260 --> 00:12:22,860
this is an image of a gravitational lens

286
00:12:28,800 --> 00:12:25,270
what's going on here is this is the

287
00:12:31,380 --> 00:12:28,810
galaxy cluster Abell 22-18 and there are

288
00:12:34,170 --> 00:12:31,390

hundreds of thousands of galaxies here

289
00:12:38,640 --> 00:12:34,180
and the combined mass of all these

290
00:12:41,400 --> 00:12:38,650
galaxies warps space via Einstein's

291
00:12:44,280 --> 00:12:41,410
theory of general relativity mass warps

292
00:12:47,190 --> 00:12:44,290
space and this cluster has enough mass

293
00:12:49,740 --> 00:12:47,200
to warp the space such that the galaxies

294
00:12:51,480 --> 00:12:49,750
that are located beyond it as their

295
00:12:54,570 --> 00:12:51,490
light passes through this warp space

296
00:12:56,730 --> 00:12:54,580
their images become stretched out and

297
00:12:59,760 --> 00:12:56,740
these become these gravitationally

298
00:13:04,380 --> 00:12:59,770
lensed arcs that you see all across this

299
00:13:06,000 --> 00:13:04,390
image Hubble is a very important tool

300
00:13:08,730 --> 00:13:06,010
for studying gravitational lenses

301
00:13:11,220 --> 00:13:08,740
because it's high resolution can see

302
00:13:15,540 --> 00:13:11,230
these small thin and sometimes very

303
00:13:18,690 --> 00:13:15,550
faint gravitationally lensed arcs also

304
00:13:20,599 --> 00:13:18,700
in 2001 we had a another serendipitous

305
00:13:24,899 --> 00:13:20,609
event here in the solar system

306
00:13:28,679 --> 00:13:24,909
this is how Mars looked in June of 2001

307
00:13:31,199 --> 00:13:28,689
and you know it's a fine picture of Mars

308
00:13:33,689 --> 00:13:31,209
and Hubble is able to sort of monitor

309
00:13:35,699 --> 00:13:33,699
Mars and monitor the other planets and

310
00:13:38,219 --> 00:13:35,709
watch what happens on them and in

311
00:13:41,159 --> 00:13:38,229
September of 2001

312
00:13:45,059 --> 00:13:41,169
a dust storm that had started down in

313
00:13:47,699 --> 00:13:45,069

the Hellas Basin became global this is a

314
00:13:50,489 --> 00:13:47,709
global dust storm on Mars which we had

315
00:13:52,829 --> 00:13:50,499
seen at other times in Mars but Hubble

316
00:13:55,349 --> 00:13:52,839
from its perch above the atmosphere is

317
00:13:57,419 --> 00:13:55,359
able to get clear images of Mars and

318
00:14:01,339 --> 00:13:57,429
able to monitor it over the years and

319
00:14:05,219 --> 00:14:01,349
catch these events as they happen in

320
00:14:06,989 --> 00:14:05,229
2002 we had servicing mission 3b as I

321
00:14:08,369 --> 00:14:06,999
said servicing mission 3a was just the

322
00:14:11,249 --> 00:14:08,379
technical part of the servicing mission

323
00:14:12,929 --> 00:14:11,259
servicing mission 3b we put in a new

324
00:14:15,629 --> 00:14:12,939
camera called the advanced camera for

325
00:14:18,329 --> 00:14:15,639
surveys now wide field planetary camera

326
00:14:21,209 --> 00:14:18,339
2 that had been the workhorse camera on

327
00:14:24,419 --> 00:14:21,219
Hubble had a resolution of one tenth of

328
00:14:27,210 --> 00:14:24,429
an arc second and ACS has a resolution

329
00:14:28,739 --> 00:14:27,220
one twentieth of an arc second so we had

330
00:14:32,489 --> 00:14:28,749
twice the resolution with this new

331
00:14:35,039 --> 00:14:32,499
camera and it covered much larger has 16

332
00:14:36,869 --> 00:14:35,049
megapixels in the camera so we had a

333
00:14:38,909 --> 00:14:36,879
great increase in the imaging

334
00:14:41,699 --> 00:14:38,919
capabilities of Hubble after servicing

335
00:14:44,699 --> 00:14:41,709
mission 3b and one of the first images

336
00:14:47,059 --> 00:14:44,709
we released was this image of the

337
00:14:49,589 --> 00:14:47,069
interacting galaxies called the mice

338
00:14:51,539 --> 00:14:49,599

what you're seeing here are two galaxies

339
00:14:53,489 --> 00:14:51,549
that have come into each other's

340
00:14:55,619 --> 00:14:53,499
gravitational influence and have started

341
00:14:57,329 --> 00:14:55,629
to interact and created these big long

342
00:14:59,549 --> 00:14:57,339
tidal tails that stretch off this side

343
00:15:02,129 --> 00:14:59,559
and stretch off this side and the two

344
00:15:04,619 --> 00:15:02,139
cores of the galaxies here in the center

345
00:15:07,289 --> 00:15:04,629
these two galaxies will eventually merge

346
00:15:09,329 --> 00:15:07,299
together and Hubble will be able to see

347
00:15:11,519 --> 00:15:09,339
all the can see all the details deep

348
00:15:16,679 --> 00:15:11,529
down into the cores of these two merging

349
00:15:19,349 --> 00:15:16,689
galaxies in 2003 we got enough image of

350
00:15:21,779 --> 00:15:19,359
a more regular galaxy this is a

351
00:15:24,869 --> 00:15:21,789
lenticular galaxy called the sombrero

352
00:15:26,429 --> 00:15:24,879
galaxy and it has sort of a disc here

353
00:15:28,949 --> 00:15:26,439
that this characteristic of spiral

354
00:15:31,649 --> 00:15:28,959
galaxies but it also has this great big

355
00:15:34,019 --> 00:15:31,659
bulge of stars that's characteristic of

356
00:15:34,410 --> 00:15:34,029
elliptical galaxies those the two

357
00:15:36,810 --> 00:15:34,420
character

358
00:15:39,360 --> 00:15:36,820
Avalon ticular galaxy that it has the

359
00:15:42,090 --> 00:15:39,370
disk like a spiral and the bolt like an

360
00:15:44,310 --> 00:15:42,100
elliptical and what this image marks for

361
00:15:46,829 --> 00:15:44,320
me is really the movement towards

362
00:15:48,810 --> 00:15:46,839
getting large mosaics of Hubble images

363
00:15:51,720 --> 00:15:48,820

because although we're showing you about

364
00:15:54,269 --> 00:15:51,730
one megapixel here in total there's

365
00:15:57,030 --> 00:15:54,279
about 70 million pixels in this image

366
00:15:59,160 --> 00:15:57,040
this is several pointings of Hubble put

367
00:16:01,350 --> 00:15:59,170
together to create a large mosaic of

368
00:16:05,780 --> 00:16:01,360
this image and these would become much

369
00:16:07,620 --> 00:16:05,790
more prevalent as the years go on now in

370
00:16:09,660 --> 00:16:07,630
2004 we got one of the most

371
00:16:11,420 --> 00:16:09,670
scientifically significant images ever

372
00:16:15,090 --> 00:16:11,430
taken with the Hubble Space Telescope

373
00:16:17,550 --> 00:16:15,100
this is the Hubble Ultra Deep Field and

374
00:16:19,920 --> 00:16:17,560
in it you can see thousands upon

375
00:16:22,379 --> 00:16:19,930
thousands of galaxies there are a few

376
00:16:24,480 --> 00:16:22,389
stars you can see one here and one here

377
00:16:26,970 --> 00:16:24,490
they have the spikes the diffraction

378
00:16:30,930 --> 00:16:26,980
spikes on them but most everything you

379
00:16:32,879 --> 00:16:30,940
see in this image is a galaxy and well

380
00:16:35,639 --> 00:16:32,889
we've got the the big galaxies that look

381
00:16:38,430 --> 00:16:35,649
sort of like our normal galaxies but if

382
00:16:41,069 --> 00:16:38,440
we zoom into this image we can go in

383
00:16:43,920 --> 00:16:41,079
until we see go past all those big

384
00:16:46,590 --> 00:16:43,930
galaxies until we see these fine small

385
00:16:49,050 --> 00:16:46,600
galaxies and really what we want to end

386
00:16:52,920 --> 00:16:49,060
up looking at is a galaxy like this

387
00:16:57,240 --> 00:16:52,930
right here it's really just a small red

388
00:17:00,170 --> 00:16:57,250

dot this galaxy is about 10 or 11 or

389
00:17:03,509 --> 00:17:00,180
maybe even 12 billion light years away

390
00:17:06,630 --> 00:17:03,519
we're seeing galaxies all the way across

391
00:17:09,179 --> 00:17:06,640
the universe in this image and that's

392
00:17:12,750 --> 00:17:09,189
what makes the whole image so important

393
00:17:15,299 --> 00:17:12,760
that as we look at this image we're

394
00:17:18,240 --> 00:17:15,309
seeing galaxies throughout the universe

395
00:17:22,079 --> 00:17:18,250
out to ten to twelve billion light-years

396
00:17:24,210 --> 00:17:22,089
away from us and because they are 12

397
00:17:26,130 --> 00:17:24,220
billion light years away the light from

398
00:17:28,680 --> 00:17:26,140
those galaxies takes about 12 billion

399
00:17:30,539 --> 00:17:28,690
years to reach us so we're seeing these

400
00:17:36,240 --> 00:17:30,549
galaxies not as they are today

401
00:17:38,580 --> 00:17:36,250
but as they were 12 billion years ago we

402
00:17:40,680 --> 00:17:38,590
are seeing galaxies across the space of

403
00:17:42,919 --> 00:17:40,690
the universe but we're also seeing

404
00:17:47,330 --> 00:17:42,929
galaxies across the time of the universe

405
00:17:52,430 --> 00:17:47,340
this one image gives us a history of

406
00:17:56,180 --> 00:17:52,440
Alexei's throughout the universe in 2005

407
00:17:58,130 --> 00:17:56,190
we got what I gotta say is my favorite

408
00:18:01,280 --> 00:17:58,140
image of a galaxy that we've ever ever

409
00:18:03,610 --> 00:18:01,290
taken this is the Whirlpool Galaxy and

410
00:18:06,920 --> 00:18:03,620
it's a classic grand design spiral

411
00:18:10,370 --> 00:18:06,930
galaxy you see the wonderful spiral arms

412
00:18:12,140 --> 00:18:10,380
now again this is a mosaic image it

413
00:18:13,880 --> 00:18:12,150

contains about a hundred million pixels

414
00:18:16,580 --> 00:18:13,890
much more resolution than you can see on

415
00:18:18,860 --> 00:18:16,590
this monitor and every single one of

416
00:18:21,500 --> 00:18:18,870
these pink regions that dot the entire

417
00:18:23,750 --> 00:18:21,510
spiral structure of the galaxy is a star

418
00:18:25,520 --> 00:18:23,760
forming region and you have to recognize

419
00:18:28,010 --> 00:18:25,530
that all of these star forming regions

420
00:18:29,990 --> 00:18:28,020
have thousands to tens of thousands of

421
00:18:31,790 --> 00:18:30,000
stars that have formed in them and when

422
00:18:34,190 --> 00:18:31,800
you start to go in detail and see all of

423
00:18:36,080 --> 00:18:34,200
the star from regions across the spiral

424
00:18:38,360 --> 00:18:36,090
structure you can really start to

425
00:18:41,690 --> 00:18:38,370
comprehend that galaxies really are made

426
00:18:44,330 --> 00:18:41,700
up of hundreds of billions of stars I

427
00:18:46,040 --> 00:18:44,340
really love this image because it really

428
00:18:49,030 --> 00:18:46,050
shows you the structure of a spiral

429
00:18:52,160 --> 00:18:49,040
galaxy and it shows you the scale of

430
00:18:53,990 --> 00:18:52,170
galaxies out there in the universe of

431
00:18:56,360 --> 00:18:54,000
course we kept coming out with really

432
00:18:59,660 --> 00:18:56,370
other fantastic images and another one

433
00:19:01,430 --> 00:18:59,670
of my favorites is the Crab Nebula now

434
00:19:03,110 --> 00:19:01,440
previously we showed you a de Carina

435
00:19:06,710 --> 00:19:03,120
which was a star that's about to go

436
00:19:08,990 --> 00:19:06,720
explode well this is a star that has

437
00:19:11,090 --> 00:19:09,000
exploded this was a star that was

438
00:19:13,850 --> 00:19:11,100

observed about a thousand years ago to

439
00:19:15,260 --> 00:19:13,860
explode and this is the nebula created

440
00:19:17,570 --> 00:19:15,270
from the explosion when the car just

441
00:19:20,090 --> 00:19:17,580
basically blows its guts across space

442
00:19:22,550 --> 00:19:20,100
and this is a thousand years later as

443
00:19:24,860 --> 00:19:22,560
the remnants of the star have spread out

444
00:19:26,690 --> 00:19:24,870
across space and I got to say these

445
00:19:29,870 --> 00:19:26,700
remnants are moving at millions of miles

446
00:19:33,230 --> 00:19:29,880
an hour to create what we call the Crab

447
00:19:35,600 --> 00:19:33,240
Nebula and I gotta say the hits keep on

448
00:19:37,150 --> 00:19:35,610
coming at this time because the next

449
00:19:39,680 --> 00:19:37,160
image I have to show you is another

450
00:19:42,980 --> 00:19:39,690
fantastic image the image of the Orion

451
00:19:45,350 --> 00:19:42,990
Nebula this is our really large mosaic I

452
00:19:48,140 --> 00:19:45,360
think at full resolution we approach a

453
00:19:49,970 --> 00:19:48,150
billion pixels in this image and this is

454
00:19:51,590 --> 00:19:49,980
perhaps our most detailed and

455
00:19:55,160 --> 00:19:51,600
spectacular image of a star-forming

456
00:19:58,310 --> 00:19:55,170
region simply because the Orion Nebula

457
00:20:01,100 --> 00:19:58,320
is the nearest of the large star forming

458
00:20:03,200 --> 00:20:01,110
regions and so deep down in here we

459
00:20:05,240 --> 00:20:03,210
can see the stars that have just formed

460
00:20:08,480 --> 00:20:05,250
the stars in here are about two million

461
00:20:10,220 --> 00:20:08,490
years old we could also see the dust the

462
00:20:12,230 --> 00:20:10,230
disks of material around these newborn

463
00:20:16,039 --> 00:20:12,240

stars where planets will be forming we

464
00:20:18,650 --> 00:20:16,049
have an incredible view of how stars and

465
00:20:23,960 --> 00:20:18,660
planets form by studying this image of

466
00:20:26,030 --> 00:20:23,970
the Orion Nebula well in 2007 we got

467
00:20:27,890 --> 00:20:26,040
another gorgeous image of a star-forming

468
00:20:30,049 --> 00:20:27,900
region but this one's at a slightly

469
00:20:31,789 --> 00:20:30,059
different stage than the Orion Nebula in

470
00:20:36,380 --> 00:20:31,799
the Orion Nebula there was still

471
00:20:38,750 --> 00:20:36,390
surrounded by its gas in NGC 602 we have

472
00:20:42,230 --> 00:20:38,760
the star cluster here but it's already

473
00:20:44,210 --> 00:20:42,240
eaten away most of the nebula they form

474
00:20:45,980 --> 00:20:44,220
the pillars that you saw before in the

475
00:20:49,820 --> 00:20:45,990
Eagle Nebula you can see the pillars up

476
00:20:53,030 --> 00:20:49,830
here and down here that that created by

477
00:20:57,320 --> 00:20:53,040
the energy and the winds from these

478
00:21:00,260 --> 00:20:57,330
bright stars in this cluster now in 2008

479
00:21:01,669 --> 00:21:00,270
we had a opportunity to see something

480
00:21:05,870 --> 00:21:01,679
we've never seen before in the solar

481
00:21:08,320 --> 00:21:05,880
system we saw three red spots on Jupiter

482
00:21:11,630 --> 00:21:08,330
now we've seen the great red spot for

483
00:21:13,010 --> 00:21:11,640
continuously since about 1820 actually

484
00:21:16,159 --> 00:21:13,020
we might have even seen it as early as

485
00:21:18,440 --> 00:21:16,169
1670 but we're not quite sure early in

486
00:21:20,990 --> 00:21:18,450
the 2000s we saw the formation of red

487
00:21:23,600 --> 00:21:21,000
spot jr. and this is the first time

488
00:21:27,680 --> 00:21:23,610

we've ever seen a red spot form on the

489
00:21:30,169 --> 00:21:27,690
planet and in May of 2008 we saw the

490
00:21:33,350 --> 00:21:30,179
formation of what we call the baby red

491
00:21:35,990 --> 00:21:33,360
spot so first time in history we saw

492
00:21:39,169 --> 00:21:36,000
three red spots on the surface of

493
00:21:41,330 --> 00:21:39,179
Jupiter unfortunately this didn't happen

494
00:21:44,330 --> 00:21:41,340
this didn't last for very long because

495
00:21:47,120 --> 00:21:44,340
over the course of 2008 we followed it

496
00:21:49,549 --> 00:21:47,130
and you can see that baby red spot is on

497
00:21:51,710 --> 00:21:49,559
the same latitude as the great red spot

498
00:21:54,140 --> 00:21:51,720
and over the course of that summer

499
00:21:56,960 --> 00:21:54,150
interacted with it and eventually broke

500
00:21:59,720 --> 00:21:56,970
up and no longer was a red spot at the

501
00:22:02,720 --> 00:21:59,730
end so Hubble was able to follow the

502
00:22:06,830 --> 00:22:02,730
formation and ultimately the destruction

503
00:22:09,500 --> 00:22:06,840
of the baby Red Spot on Jupiter well in

504
00:22:10,700 --> 00:22:09,510
2009 Servicing magician for finally

505
00:22:13,130 --> 00:22:10,710
happened this was something that was

506
00:22:14,570 --> 00:22:13,140
scheduled for several years earlier but

507
00:22:15,560 --> 00:22:14,580
due to this

508
00:22:18,590 --> 00:22:15,570
accident of the space shuttle Columbia

509
00:22:21,500 --> 00:22:18,600
was delayed for several years but in May

510
00:22:23,840 --> 00:22:21,510
2009 we have this image of astronaut

511
00:22:28,190 --> 00:22:23,850
drew boy still working on his very first

512
00:22:30,560 --> 00:22:28,200
spacewalk and in during the during

513
00:22:32,090 --> 00:22:30,570

servicing mission for we installed two

514
00:22:35,510 --> 00:22:32,100
brand new instruments Wide Field Camera

515
00:22:38,870 --> 00:22:35,520
3 and the cosmic origins spectrograph to

516
00:22:40,820 --> 00:22:38,880
add to Hubble's capabilities the early

517
00:22:43,550 --> 00:22:40,830
riess observations were absolutely

518
00:22:45,380 --> 00:22:43,560
spectacular this was one of the first

519
00:22:48,380 --> 00:22:45,390
early Rees observations a planetary

520
00:22:49,970 --> 00:22:48,390
nebula called the bug nebula although in

521
00:22:51,920 --> 00:22:49,980
our press release we refer to it as the

522
00:22:54,050 --> 00:22:51,930
butterfly nebula and that name seems to

523
00:22:55,760 --> 00:22:54,060
a stick it really does fit because it

524
00:22:57,770 --> 00:22:55,770
does look like a butterfly these are

525
00:23:00,110 --> 00:22:57,780
actually hourglass shape lobes of

526
00:23:03,410 --> 00:23:00,120
material streaming away from the dying

527
00:23:05,360 --> 00:23:03,420
star at its center absolutely gorgeous

528
00:23:08,240 --> 00:23:05,370
shows that Hubble is back in business

529
00:23:10,010 --> 00:23:08,250
but this image also from the

530
00:23:12,740 --> 00:23:10,020
early-release observations of the

531
00:23:15,470 --> 00:23:12,750
central regions of omega centauri shows

532
00:23:18,230 --> 00:23:15,480
off the new capabilities this is a

533
00:23:20,270 --> 00:23:18,240
combined infrared and ultraviolet image

534
00:23:23,210 --> 00:23:20,280
there's actually no visible light in

535
00:23:25,520 --> 00:23:23,220
this image the red stars are the stars

536
00:23:27,560 --> 00:23:25,530
that shine bright in infrared and the

537
00:23:30,020 --> 00:23:27,570
blue stars of the stars that shine

538
00:23:31,760 --> 00:23:30,030

bright in the ultraviolet and we can

539
00:23:34,820 --> 00:23:31,770
pick out sort of the extremes of

540
00:23:37,510 --> 00:23:34,830
temperatures within omega sin with our

541
00:23:42,410 --> 00:23:37,520
new capabilities of Wide Field Camera 3

542
00:23:45,320 --> 00:23:42,420
so that is 19 years of hull imagery and

543
00:23:47,420 --> 00:23:45,330
for the 20th anniversary we had to come

544
00:23:48,890 --> 00:23:47,430
up with something spectacular we had to

545
00:23:51,110 --> 00:23:48,900
say all right how are we really gonna

546
00:23:52,970 --> 00:23:51,120
celebrate this but we've got so much

547
00:23:55,600 --> 00:23:52,980
gorgeous imagery could we really come up

548
00:23:59,900 --> 00:23:55,610
with something really spectacular I

549
00:24:02,990 --> 00:23:59,910
happen to think that yes he did this is

550
00:24:06,650 --> 00:24:03,000
our 20th anniversary image a pillar in

551
00:24:09,620 --> 00:24:06,660
the Carina Nebula now this is like the

552
00:24:11,660 --> 00:24:09,630
pillar in eel nebula in that the pillars

553
00:24:13,820 --> 00:24:11,670
are being carved out by those

554
00:24:16,550 --> 00:24:13,830
high-energy radiation and winds from

555
00:24:20,690 --> 00:24:16,560
bright stars but it's absolutely a

556
00:24:24,470 --> 00:24:20,700
gorgeous gorgeous view of a pillar in

557
00:24:26,500 --> 00:24:24,480
Carina and it includes at the top of

558
00:24:28,250 --> 00:24:26,510
this pillar and the top of this pillar

559
00:24:31,520 --> 00:24:28,260
jets from Nouveau

560
00:24:33,380 --> 00:24:31,530
stars when stars first turn on they send

561
00:24:35,660 --> 00:24:33,390
out these oppositely directed Jets that

562
00:24:37,760 --> 00:24:35,670
spew out and announce their birth where

563
00:24:39,860 --> 00:24:37,770

you can see them a star has just formed

564
00:24:42,170 --> 00:24:39,870
the top of this pillar and one that has

565
00:24:45,530 --> 00:24:42,180
formed at the top of this pillar this is

566
00:24:47,360 --> 00:24:45,540
an incredible image and having learned

567
00:24:50,180 --> 00:24:47,370
what we did in creating the imax film

568
00:24:55,160 --> 00:24:50,190
Hubble 3d we were able to put this one

569
00:24:57,110 --> 00:24:55,170
into 3d motion this in this animation

570
00:24:59,090 --> 00:24:57,120
what we've done is we've taken the

571
00:25:01,100 --> 00:24:59,100
pillars and Carina Nebula we've

572
00:25:03,860 --> 00:25:01,110
separated out layers of stars we've

573
00:25:06,800 --> 00:25:03,870
separated out layers of the pillar and

574
00:25:09,500 --> 00:25:06,810
we have pulled them into a 3d program

575
00:25:12,500 --> 00:25:09,510
and allowed us to fly through it in 3d

576
00:25:14,630 --> 00:25:12,510
to give you a sort of 3d feel now this

577
00:25:17,120 --> 00:25:14,640
is not scientifically accurate but it

578
00:25:23,870 --> 00:25:17,130
gives you a 3d feel for the structure of

579
00:25:30,740 --> 00:25:27,799
so that's it that's 20 images for 20

580
00:25:33,710 --> 00:25:30,750
years of Hubble now 20 images is

581
00:25:36,140 --> 00:25:33,720
relatively small because Hubble has

582
00:25:38,150 --> 00:25:36,150
actually released of over a thousand

583
00:25:40,400 --> 00:25:38,160
public release images it's taken nearly

584
00:25:43,190 --> 00:25:40,410
a million observations we have released

585
00:25:46,220 --> 00:25:43,200
over a thousand public release images

586
00:25:48,890 --> 00:25:46,230
and here is April almost mind-boggling

587
00:25:50,840 --> 00:25:48,900
montage of Hubble images so if I didn't

588
00:25:54,529 --> 00:25:50,850

cover your favorite one perhaps you can

589
00:25:57,320 --> 00:25:54,539
see it in this montage I'd like to

590
00:25:59,630 --> 00:25:57,330
finish with one last image this is a

591
00:26:02,419 --> 00:25:59,640
sort of poetic image of Hubble hanging

592
00:26:04,130 --> 00:26:02,429
over the limb of Earth but this this

593
00:26:06,500 --> 00:26:04,140
image has even a little bit more meaning

594
00:26:09,140 --> 00:26:06,510
to us because this is the last image

595
00:26:11,360 --> 00:26:09,150
from servicing mission 4 and servicing

596
00:26:12,890 --> 00:26:11,370
mission 4 is the last shuttle mission to

597
00:26:15,529 --> 00:26:12,900
Hubble simply because the shuttle

598
00:26:18,770 --> 00:26:15,539
program is ending so this is sort of the

599
00:26:21,409 --> 00:26:18,780
the last view that humans had of the

600
00:26:23,600 --> 00:26:21,419
Hubble Space Telescope now you can see

601
00:26:27,049 --> 00:26:23,610
that Hubble is really just above Earth's

602
00:26:28,460 --> 00:26:27,059
atmosphere and as an astronomer early on

603
00:26:30,500 --> 00:26:28,470
I thought that putting Hubble in

604
00:26:32,090 --> 00:26:30,510
low-earth orbit was a problem because

605
00:26:35,029 --> 00:26:32,100
you've got the earth there you've got

606
00:26:37,520 --> 00:26:35,039
the Van Allen belts radiation around it

607
00:26:39,169 --> 00:26:37,530
you're going from day to night every 90

608
00:26:41,320 --> 00:26:39,179
minutes it really causes a lot of

609
00:26:44,930 --> 00:26:41,330
problems for astronomical observations

610
00:26:47,090 --> 00:26:44,940
however having Hubble in low-earth orbit

611
00:26:50,480 --> 00:26:47,100
and being able to send shuttle missions

612
00:26:53,899 --> 00:26:50,490
up to repair it has enabled Hubble to

613
00:26:56,240 --> 00:26:53,909

stay current we are able to take out the

614
00:26:59,210 --> 00:26:56,250
old instruments and put in new

615
00:27:02,419 --> 00:26:59,220
technology which keeps Hubble current

616
00:27:04,659 --> 00:27:02,429
one I mean you've seen the changes in

617
00:27:07,970 --> 00:27:04,669
this episode of the Hubble observations

618
00:27:11,090 --> 00:27:07,980
but it also provides changes in what

619
00:27:13,340 --> 00:27:11,100
Hubble can study Hubble has made

620
00:27:17,270 --> 00:27:13,350
significant contributions to the study

621
00:27:19,460 --> 00:27:17,280
of dark energy when we had no idea that

622
00:27:21,500 --> 00:27:19,470
that scientific problem was even going

623
00:27:24,649 --> 00:27:21,510
to be around woodhull was on the drawing

624
00:27:27,049 --> 00:27:24,659
board changing out the instruments has

625
00:27:29,390 --> 00:27:27,059
enabled Howell to not only increase its

626
00:27:31,570 --> 00:27:29,400
vision of the universe but also to

627
00:27:34,430 --> 00:27:31,580
increase the number of scientific

628
00:27:36,649 --> 00:27:34,440
capable scientific questions that Hubble

629
00:27:37,670 --> 00:27:36,659
can answer and that is one of its

630
00:27:40,700 --> 00:27:37,680
legacies

631
00:27:44,240 --> 00:27:40,710
an orbiting observatory can change and

632
00:27:47,720 --> 00:27:44,250
adapt and address brand new problems

633
00:27:49,060 --> 00:27:47,730
over its 20 years and of course Hubble

634
00:27:51,530 --> 00:27:49,070
is not finished yet

635
00:27:53,870 --> 00:27:51,540
after servicing mission 4 is in

636
00:27:55,040 --> 00:27:53,880
wonderful condition we expect it to last

637
00:27:57,680 --> 00:27:55,050
for another 10 years

638
00:27:59,900 --> 00:27:57,690

who knows maybe more and how we'll be

639
00:28:02,480 --> 00:27:59,910
able to lure a lot more beautiful images

640
00:28:03,550 --> 00:28:02,490
and a lot more cutting-edge science for

641
00:28:06,080 --> 00:28:03,560
years to come

642
00:28:07,610 --> 00:28:06,090
thank you for joining us we'll see you

643
00:28:09,540 --> 00:28:07,620
next time on Hubble's universe