
EPISODE 3
TIME MACHINES

1
00:00:10,310 --> 00:00:08,070
we are locked and we are going to send

2
00:00:11,910 --> 00:00:10,320
that command

3
00:00:12,870 --> 00:00:11,920
31 minutes and 32 seconds for our

4
00:00:15,270 --> 00:00:12,880
support

5
00:00:18,310 --> 00:00:15,280
[Music]

6
00:00:19,910 --> 00:00:18,320
go for status buffer dump

7
00:00:21,830 --> 00:00:19,920
what you're looking at with a telescope

8
00:00:24,310 --> 00:00:21,840
of course is the light from billions of

9
00:00:25,990 --> 00:00:24,320
light years away so the further you look

10
00:00:28,150 --> 00:00:26,000
the more you're going back towards the

11
00:00:30,710 --> 00:00:28,160
big bang and understanding how the

12
00:00:32,470 --> 00:00:30,720
universe was formed

13
00:00:35,430 --> 00:00:32,480

the webb telescope will be ground

14
00:00:37,110 --> 00:00:35,440
breaking because it has capabilities

15
00:00:38,950 --> 00:00:37,120
that are different than the hubble space

16
00:00:40,790 --> 00:00:38,960
telescope

17
00:00:42,470 --> 00:00:40,800
we have equipment that is so much more

18
00:00:44,790 --> 00:00:42,480
powerful than anything we've ever had

19
00:00:47,420 --> 00:00:44,800
before that it's almost impossible to

20
00:00:59,029 --> 00:00:47,430
tell what we will discover

21
00:01:03,830 --> 00:01:01,510
hubble's accomplishments include

22
00:01:05,429 --> 00:01:03,840
something called the deep feels

23
00:01:06,789 --> 00:01:05,439
looking out

24
00:01:08,870 --> 00:01:06,799
into space

25
00:01:11,590 --> 00:01:08,880
and collecting light sometimes for many

26
00:01:13,190 --> 00:01:11,600
days these deep feels have revealed

27
00:01:15,749 --> 00:01:13,200
visually to us

28
00:01:17,590 --> 00:01:15,759
a universe absolutely teeming with

29
00:01:20,290 --> 00:01:17,600
galaxies hundreds of billions of

30
00:01:23,590 --> 00:01:22,070
[Music]

31
00:01:25,109 --> 00:01:23,600
one of the neat things about the ultra

32
00:01:27,749 --> 00:01:25,119
deep field and one of the things that

33
00:01:29,910 --> 00:01:27,759
made it so unique was was how long it

34
00:01:31,510 --> 00:01:29,920
took us to take that image there's an

35
00:01:34,230 --> 00:01:31,520
exposure time that's expressed i think

36
00:01:36,310 --> 00:01:34,240
it's 11.2 days it's a very very long

37
00:01:38,870 --> 00:01:36,320
exposure time but probably what's more

38
00:01:42,710 --> 00:01:38,880

important is how many orbits it took us

39
00:01:45,109 --> 00:01:42,720
to do that 400 orbits of hubble data to

40
00:01:48,149 --> 00:01:45,119
take that image you only get 15 orbits a

41
00:01:49,910 --> 00:01:48,159
day to take 400 orbits

42
00:01:53,190 --> 00:01:49,920
and say we're going to observe this one

43
00:01:55,510 --> 00:01:53,200
spot in the sky for 400 orbits and the

44
00:01:57,190 --> 00:01:55,520
really unique thing about that was they

45
00:01:59,270 --> 00:01:57,200
picked a spot where there wasn't

46
00:02:01,350 --> 00:01:59,280
anything they looked and they said

47
00:02:04,230 --> 00:02:01,360
there's absolutely nothing here and they

48
00:02:06,230 --> 00:02:04,240
said you want to spend 400 hubble orbits

49
00:02:08,389 --> 00:02:06,240
looking at nothing and they said yes

50
00:02:10,150 --> 00:02:08,399
because we want to see what it can see

51
00:02:12,070 --> 00:02:10,160
and i think the results from the science

52
00:02:15,190 --> 00:02:12,080
i mean it was amazing what they saw was

53
00:02:15,200 --> 00:02:18,550
[Music]

54
00:02:22,390 --> 00:02:20,470
hubble spent two weeks taking pictures

55
00:02:23,750 --> 00:02:22,400
of empty places in sky

56
00:02:25,030 --> 00:02:23,760
and they saw they weren't empty at all

57
00:02:28,630 --> 00:02:25,040
they were thousands and thousands of

58
00:02:33,190 --> 00:02:30,949
we were amazed how many galaxies we've

59
00:02:35,589 --> 00:02:33,200
we've found and we continue to go back

60
00:02:40,229 --> 00:02:35,599
to that portion of the sky to increase

61
00:02:44,550 --> 00:02:42,949
the hubble space telescope is

62
00:02:47,030 --> 00:02:44,560
an outstanding

63
00:02:49,030 --> 00:02:47,040

time machine

64
00:02:50,949 --> 00:02:49,040
it's incredibly important for our

65
00:02:53,750 --> 00:02:50,959
studies with the hubble space telescope

66
00:02:56,869 --> 00:02:53,760
to realize that when we're looking at a

67
00:02:59,030 --> 00:02:56,879
galaxy we're seeing it as it was

68
00:03:01,270 --> 00:02:59,040
millions of years ago sometimes billions

69
00:03:03,270 --> 00:03:01,280
of years ago it's taken that long for

70
00:03:04,869 --> 00:03:03,280
the light to get to us

71
00:03:06,790 --> 00:03:04,879
what you're looking at with a telescope

72
00:03:09,270 --> 00:03:06,800
of course is the light from billions of

73
00:03:10,949 --> 00:03:09,280
light years away so the further you look

74
00:03:13,110 --> 00:03:10,959
the more you're going back towards the

75
00:03:15,910 --> 00:03:13,120
big bang and understanding how the

76
00:03:18,229 --> 00:03:15,920
universe was formed

77
00:03:21,110 --> 00:03:18,239
what hubble has revealed is that the

78
00:03:23,670 --> 00:03:21,120
universe has in fact changed over these

79
00:03:25,990 --> 00:03:23,680
billions of years of time the early

80
00:03:26,949 --> 00:03:26,000
galaxies the very distant ones as we see

81
00:03:27,750 --> 00:03:26,959
them

82
00:03:29,750 --> 00:03:27,760
are

83
00:03:32,149 --> 00:03:29,760
simple sometimes they're messy looking

84
00:03:35,190 --> 00:03:32,159
they're small they haven't had time yet

85
00:03:37,670 --> 00:03:35,200
to form that grand spiral structure

86
00:03:40,070 --> 00:03:37,680
over time we see galaxies actually

87
00:03:42,229 --> 00:03:40,080
merging with other galaxies and growing

88
00:03:44,149 --> 00:03:42,239

bigger and bigger and those mergers can

89
00:03:45,840 --> 00:03:44,159
look like train wrecks in our hubble

90
00:03:51,509 --> 00:03:45,850
images

91
00:03:53,350 --> 00:03:51,519
[Music]

92
00:03:54,630 --> 00:03:53,360
these very very deep exposures that

93
00:03:57,110 --> 00:03:54,640
hubble has been able to take we have

94
00:04:00,869 --> 00:03:57,120
seen right to the edge of the universe

95
00:04:02,470 --> 00:04:00,879
13 and a half billion years

96
00:04:04,070 --> 00:04:02,480
when hubble was first designed and

97
00:04:06,869 --> 00:04:04,080
envisioned it was never thought it could

98
00:04:08,630 --> 00:04:06,879
actually see that far out but because of

99
00:04:09,750 --> 00:04:08,640
the advances in the instruments that

100
00:04:11,910 --> 00:04:09,760
we've been able to put up on the

101
00:04:13,589 --> 00:04:11,920
telescope and also the cleverness of the

102
00:04:15,509 --> 00:04:13,599
scientists they've come up with very

103
00:04:17,430 --> 00:04:15,519
interesting observing scenarios doing

104
00:04:19,110 --> 00:04:17,440
these really deep exposures where we

105
00:04:20,310 --> 00:04:19,120
just sit there for orbit after orbit

106
00:04:22,390 --> 00:04:20,320
after orbit

107
00:04:24,100 --> 00:04:22,400
gathering the photons we've been able to

108
00:04:26,629 --> 00:04:24,110
push hubble out very very far

109
00:04:29,670 --> 00:04:26,639
[Music]

110
00:04:32,150 --> 00:04:29,680
as hubble looks out into these

111
00:04:34,310 --> 00:04:32,160
fields of galaxies we sometimes see

112
00:04:36,150 --> 00:04:34,320
clusters of galaxies these are galaxies

113
00:04:38,629 --> 00:04:36,160

that are held nearby each other by their

114
00:04:41,110 --> 00:04:38,639
mutual gravity

115
00:04:44,230 --> 00:04:41,120
these clusters are

116
00:04:47,749 --> 00:04:44,240
massive conglomerations there's so much

117
00:04:51,030 --> 00:04:47,759
mass that they have an actual observable

118
00:04:54,230 --> 00:04:51,040
impact on space time itself

119
00:04:56,070 --> 00:04:54,240
einstein predicted that mass distorts

120
00:04:58,070 --> 00:04:56,080
space but we didn't realize we could

121
00:05:00,710 --> 00:04:58,080
actually see the effects of that but

122
00:05:03,189 --> 00:05:00,720
with hubble we have been able to see

123
00:05:05,909 --> 00:05:03,199
distortions in space around clusters of

124
00:05:08,790 --> 00:05:05,919
galaxies the way we see that is when

125
00:05:11,110 --> 00:05:08,800
light from a background galaxy travels

126
00:05:13,430 --> 00:05:11,120
through that cluster of galaxies or

127
00:05:15,749 --> 00:05:13,440
around it due to this gravitational

128
00:05:18,870 --> 00:05:15,759
lensing effect the lensing also

129
00:05:20,950 --> 00:05:18,880
magnifies that background galaxy so if

130
00:05:22,870 --> 00:05:20,960
we look in some of these distorted arcs

131
00:05:24,790 --> 00:05:22,880
we can see more detail than we would

132
00:05:27,830 --> 00:05:24,800
ever have been able to see

133
00:05:31,749 --> 00:05:27,840
without gravitational lensing nature's

134
00:05:36,150 --> 00:05:33,670
there are observations where we're

135
00:05:38,550 --> 00:05:36,160
explicitly looking for the lensing and

136
00:05:41,670 --> 00:05:38,560
they're getting science out of that that

137
00:05:44,469 --> 00:05:41,680
just otherwise would just not be doable

138
00:05:45,510 --> 00:05:44,479

hubble has really taken that to a next

139
00:05:48,150 --> 00:05:45,520
level

140
00:05:49,909 --> 00:05:48,160
it's doing large amounts of astrophysics

141
00:05:55,350 --> 00:05:49,919
that it's just never been able to do

142
00:05:59,990 --> 00:05:57,510
some of what we're doing with hubble is

143
00:06:02,230 --> 00:06:00,000
to prepare for the new james webb

144
00:06:05,510 --> 00:06:02,240
telescope which we anticipate launching

145
00:06:07,510 --> 00:06:05,520
in 2021 which will be able to see

146
00:06:10,390 --> 00:06:07,520
farther into the infrared part of the

147
00:06:13,510 --> 00:06:10,400
electromagnetic spectrum that enables us

148
00:06:15,749 --> 00:06:13,520
to see some galaxies that are

149
00:06:18,150 --> 00:06:15,759
difficult for hubble to see

150
00:06:20,550 --> 00:06:18,160
because they're so far away

151
00:06:22,309 --> 00:06:20,560
that their light is traveling through us

152
00:06:24,870 --> 00:06:22,319
through expanding space and gets

153
00:06:27,189 --> 00:06:24,880
stretched out into redder wavelengths

154
00:06:28,309 --> 00:06:27,199
often far into the infrared part of the

155
00:06:30,309 --> 00:06:28,319
spectrum

156
00:06:32,790 --> 00:06:30,319
even sometimes beyond what hubble is

157
00:06:34,390 --> 00:06:32,800
able to detect well the web telescope

158
00:06:38,230 --> 00:06:34,400
will give us more information about some

159
00:06:41,590 --> 00:06:40,070
the james webb space telescope is the

160
00:06:43,189 --> 00:06:41,600
follow-on telescope after the great

161
00:06:45,189 --> 00:06:43,199
hubble telescope

162
00:06:47,800 --> 00:06:45,199
it extends the discoveries of hubble

163
00:06:49,270 --> 00:06:47,810

into the infrared spectrum region

164
00:06:50,870 --> 00:06:49,280
[Music]

165
00:06:52,390 --> 00:06:50,880
we think that the first objects that

166
00:06:54,390 --> 00:06:52,400
grew out of the big bang material

167
00:06:57,350 --> 00:06:54,400
probably happened in about 100 million

168
00:06:59,029 --> 00:06:57,360
years after the start

169
00:07:00,790 --> 00:06:59,039
and we think the webb telescope can pick

170
00:07:04,070 --> 00:07:00,800
them up they're rare they're hard to

171
00:07:07,830 --> 00:07:05,430
the farthest we've been able to see with

172
00:07:09,990 --> 00:07:07,840
the hubble telescope goes back about

173
00:07:10,950 --> 00:07:10,000
6 800 million years after the expansion

174
00:07:11,670 --> 00:07:10,960
began

175
00:07:13,589 --> 00:07:11,680
so

176
00:07:17,749 --> 00:07:13,599
we think we'll get a much much closer to

177
00:07:19,510 --> 00:07:17,759
the first objects with the web telescope

178
00:07:21,749 --> 00:07:19,520
hubble gives information that the web

179
00:07:24,309 --> 00:07:21,759
telescope cannot give about visible and

180
00:07:25,830 --> 00:07:24,319
ultraviolet emission from things in the

181
00:07:28,390 --> 00:07:25,840
universe and when we have all that

182
00:07:32,390 --> 00:07:28,400
information coming in at the same time

183
00:07:34,309 --> 00:07:32,400
it's like a banquet of scientific return

184
00:07:35,990 --> 00:07:34,319
now when we get the complete picture of

185
00:07:38,390 --> 00:07:36,000
every wavelength you can possibly see

186
00:07:40,070 --> 00:07:38,400
from ultraviolet to infrared we hope to

187
00:07:41,749 --> 00:07:40,080
have the story of the growth of the

188
00:07:44,070 --> 00:07:41,759

first galaxies from the primordial

189
00:07:46,070 --> 00:07:44,080
material so that will be a huge

190
00:07:47,990 --> 00:07:46,080
accomplishment that depends on both

191
00:07:49,909 --> 00:07:48,000
pieces of equipment the hubble telescope

192
00:07:51,830 --> 00:07:49,919
and the james webb telescope working

193
00:07:54,309 --> 00:07:51,840
together

194
00:07:55,990 --> 00:07:54,319
so astronomers are very excited about

195
00:07:57,909 --> 00:07:56,000
this probability that we'll have both

196
00:08:00,230 --> 00:07:57,919
the hubble space telescope and the webb

197
00:08:02,070 --> 00:08:00,240
telescope operating at the same time for

198
00:08:04,230 --> 00:08:02,080
quite a few years that will give us an

199
00:08:06,390 --> 00:08:04,240
abundance of new understanding about the

200
00:08:08,629 --> 00:08:06,400
universe and already right now with

201
00:08:11,430 --> 00:08:08,639
hubble we're doing preparatory

202
00:08:13,670 --> 00:08:11,440
observations for the web telescope we're

203
00:08:16,070 --> 00:08:13,680
using hubble to do things for example

204
00:08:19,510 --> 00:08:16,080
like surveying distant galaxies to find

205
00:08:21,670 --> 00:08:19,520
out which ones would be prime targets

206
00:08:23,430 --> 00:08:21,680
for the webb telescope in fact

207
00:08:25,430 --> 00:08:23,440
scientists around the world

208
00:08:26,390 --> 00:08:25,440
are proposing observations with hubble

209
00:08:28,390 --> 00:08:26,400
right now

210
00:08:30,629 --> 00:08:28,400
specifically to help us learn

211
00:08:32,550 --> 00:08:30,639
information that will be useful

212
00:08:34,949 --> 00:08:32,560
for making the best use of the web

213
00:08:39,269 --> 00:08:34,959

telescope as soon as it's launched and

214
00:08:42,389 --> 00:08:40,790
i think the hubble telescope has been

215
00:08:44,550 --> 00:08:42,399
the most productive science instrument

216
00:08:46,310 --> 00:08:44,560
ever built in astronomy there's what we

217
00:08:47,910 --> 00:08:46,320
knew before hubble and now there's what

218
00:08:49,829 --> 00:08:47,920
we know after hubble they're so

219
00:08:52,070 --> 00:08:49,839
different of course hubble has now had a

220
00:08:54,230 --> 00:08:52,080
life of 30 years so it's had a long time

221
00:08:56,630 --> 00:08:54,240
to make this revolution happen so it's

222
00:08:58,150 --> 00:08:56,640
not all at once it's a gradual

223
00:09:00,550 --> 00:08:58,160
revolution but it's still a huge

224
00:09:02,550 --> 00:09:00,560
revolution

225
00:09:04,310 --> 00:09:02,560
technology has changed dramatically over

226
00:09:06,870 --> 00:09:04,320
the 30 years of life of the hubble

227
00:09:08,550 --> 00:09:06,880
telescope so you couldn't even have

228
00:09:10,310 --> 00:09:08,560
imagined when the hubble was launched

229
00:09:12,949 --> 00:09:10,320
that we would have the wonderful cameras

230
00:09:14,870 --> 00:09:12,959
and spectrometers that we fly today

231
00:09:16,949 --> 00:09:14,880
we figured out how to send astronauts we

232
00:09:18,870 --> 00:09:16,959
trained the astronauts we figured out

233
00:09:20,150 --> 00:09:18,880
what instruments could be put in we

234
00:09:22,230 --> 00:09:20,160
figured out how to repair everything

235
00:09:24,710 --> 00:09:22,240
that went wrong on the hubble and it's

236
00:09:27,509 --> 00:09:24,720
still alive it's today 30 years after

237
00:09:29,750 --> 00:09:27,519
launch and i am so thrilled to say that

238
00:09:31,670 --> 00:09:29,760

our people were able to do that

239
00:09:33,670 --> 00:09:31,680
that's the operations team that makes

240
00:09:34,870 --> 00:09:33,680
this possible it's a miracle as far as

241
00:09:38,020 --> 00:09:34,880
i'm concerned because it didn't have to