
Google+
Scott Wolk
Chandra X_ray Center - SA
Scott
ve O'Dell
gan Watzke
e Hlavacek-Larrondo
vey Tananbaum

1
00:00:10,520 --> 00:00:08,600
good afternoon everyone and thank you

2
00:00:12,500 --> 00:00:10,530
for joining us on today's NASA Google+

3
00:00:14,450 --> 00:00:12,510
hangout we're very excited to celebrate

4
00:00:17,150 --> 00:00:14,460
a very important and special occasion

5
00:00:18,440 --> 00:00:17,160
it's the 15th anniversary or birthday so

6
00:00:21,650 --> 00:00:18,450
to speak of the Chandra x-ray

7
00:00:24,890 --> 00:00:21,660
Observatory almost exactly 15 years ago

8
00:00:26,660 --> 00:00:24,900
on July 23rd 1999 the space shuttle

9
00:00:29,540 --> 00:00:26,670
Columbia took off from Kennedy Space

10
00:00:33,080 --> 00:00:29,550
Flight Center just after midnight at the

11
00:00:34,819 --> 00:00:33,090
helm of the mission known as STS 93 was

12
00:00:38,240 --> 00:00:34,829
Eileen Collins the first woman ever to

13
00:00:39,889 --> 00:00:38,250

lead a NASA mission into space STS 93

14
00:00:42,139 --> 00:00:39,899
was also historic for what was in

15
00:00:44,299 --> 00:00:42,149
Columbia's payload Bay the Chandra x-ray

16
00:00:47,180 --> 00:00:44,309
Observatory the Chandra x-ray

17
00:00:50,090 --> 00:00:47,190
Observatory is NASA's crown jewel for

18
00:00:52,430 --> 00:00:50,100
x-ray astronomy net Chandra is also one

19
00:00:54,200 --> 00:00:52,440
of NASA's Great observatories along with

20
00:00:56,240 --> 00:00:54,210
the Hubble Space Telescope spitzer space

21
00:00:59,330 --> 00:00:56,250
telescope and coming to gamma ray

22
00:01:01,430 --> 00:00:59,340
Observatory the Chandra x-ray

23
00:01:03,650 --> 00:01:01,440
observatory has exquisite x-ray

24
00:01:06,230 --> 00:01:03,660
resolution and sensitivity which allows

25
00:01:08,330 --> 00:01:06,240
it to see objects such as the debris

26
00:01:10,550 --> 00:01:08,340
from exploded stars matter falling into

27
00:01:14,240 --> 00:01:10,560
black holes and galaxy clusters that are

28
00:01:15,950 --> 00:01:14,250
filled with hot gas we are very

29
00:01:18,289 --> 00:01:15,960
fortunate to have a distinguished panel

30
00:01:20,510 --> 00:01:18,299
of guests today to explain and explore

31
00:01:22,399 --> 00:01:20,520
Chander's 15 years in space and in

32
00:01:24,590 --> 00:01:22,409
science in fact these are some of the

33
00:01:26,210 --> 00:01:24,600
people who conceived of built and

34
00:01:28,190 --> 00:01:26,220
developed and tested Chandra on the

35
00:01:30,800 --> 00:01:28,200
ground we also have guests who are

36
00:01:33,020 --> 00:01:30,810
actively using Chandra to better explore

37
00:01:35,480 --> 00:01:33,030
our universe today and continues to make

38
00:01:37,039 --> 00:01:35,490

the scientific discoveries before I

39
00:01:38,660 --> 00:01:37,049
introduce our panelists though I do want

40
00:01:40,820 --> 00:01:38,670
to bring up a graphic the woman

41
00:01:42,469 --> 00:01:40,830
displayed two websites that have a

42
00:01:44,330 --> 00:01:42,479
wealth of information that you can

43
00:01:46,249 --> 00:01:44,340
explore during today's Google+ Hangout

44
00:01:47,390 --> 00:01:46,259
if I can have those two graphics with

45
00:01:50,450 --> 00:01:47,400
those two URLs

46
00:01:55,700 --> 00:01:50,460
there's the NASA dr. of size Chandra and

47
00:01:57,410 --> 00:01:55,710
also Chandra decidd you slash 15 and

48
00:01:59,990 --> 00:01:57,420
also if you are interested in asking a

49
00:02:02,899 --> 00:02:00,000
question today you may use the ask NASA

50
00:02:05,990 --> 00:02:02,909
hashtag or leave a comment on the Google

51
00:02:08,899 --> 00:02:06,000
events Google+ events page now let's

52
00:02:11,119 --> 00:02:08,909
Mary speakers Harvey Tannenbaum is a

53
00:02:12,769 --> 00:02:11,129
senior astrophysicist at the Smithsonian

54
00:02:14,000 --> 00:02:12,779
Astrophysical Observatory in Cambridge

55
00:02:15,410 --> 00:02:14,010
Massachusetts and

56
00:02:18,530 --> 00:02:15,420
so the former director of the Chandra

57
00:02:20,600 --> 00:02:18,540
x-ray Center Stephen Odell is the deputy

58
00:02:21,830 --> 00:02:20,610
project scientist for Chandra at the

59
00:02:25,160 --> 00:02:21,840
Marshall Space Flight Center in

60
00:02:27,259 --> 00:02:25,170
Huntsville Alabama julie guava check

61
00:02:29,420 --> 00:02:27,269
llorando is an assistant professor of

62
00:02:31,759 --> 00:02:29,430
physics at the University of Montreal in

63
00:02:33,710 --> 00:02:31,769

Canada and Scott Wilk is an

64
00:02:36,500 --> 00:02:33,720
astrophysicist also at the Smithsonian

65
00:02:37,729 --> 00:02:36,510
Astrophysical Observatory uh without any

66
00:02:38,600 --> 00:02:37,739
further ado let me turn it over to

67
00:02:41,750 --> 00:02:38,610
Harvey to get us started

68
00:02:43,699 --> 00:02:41,760
Harvey thanks Megan it's really great to

69
00:02:45,289 --> 00:02:43,709
be here today and have a chance to talk

70
00:02:48,920 --> 00:02:45,299
about Chandra which of course is very

71
00:02:53,599 --> 00:02:48,930
very special to me from 1991 until this

72
00:02:55,520 --> 00:02:53,609
past April I was the director of the

73
00:02:58,369 --> 00:02:55,530
Chandra x-ray Center here in Cambridge

74
00:03:01,039 --> 00:02:58,379
and prior to that I had led the team of

75
00:03:03,619 --> 00:03:01,049
Sao scientists and engineers who worked

76
00:03:05,569 --> 00:03:03,629
with Marshall Space Flight Center to

77
00:03:07,940 --> 00:03:05,579
oversee this mission from its inception

78
00:03:10,399 --> 00:03:07,950
nearly 40 years ago so there's a real

79
00:03:13,069 --> 00:03:10,409
long history there we have this first

80
00:03:15,800 --> 00:03:13,079
animation this is a picture showing that

81
00:03:17,349 --> 00:03:15,810
Chandra in fact is a space mission we

82
00:03:20,030 --> 00:03:17,359
have to fly above the Earth's atmosphere

83
00:03:23,180 --> 00:03:20,040
in order to be able to detect x-rays

84
00:03:25,280 --> 00:03:23,190
from stars and galaxies when we get up

85
00:03:27,080 --> 00:03:25,290
above the atmosphere to image an x-ray

86
00:03:29,809 --> 00:03:27,090
source we need a very special kind of

87
00:03:33,680 --> 00:03:29,819
telescope we need to be able to image

88
00:03:36,530 --> 00:03:33,690

x-rays and to do that we take the inside

89
00:03:38,839 --> 00:03:36,540
walls of cylindrical shaped mirrors we

90
00:03:41,569 --> 00:03:38,849
bounce or scatter the x-rays reflect the

91
00:03:44,240 --> 00:03:41,579
x-rays from those inside walls and after

92
00:03:46,369 --> 00:03:44,250
two reflections we get them a very nice

93
00:03:49,039 --> 00:03:46,379
image about 30 feet down the road in the

94
00:03:51,890 --> 00:03:49,049
case of Chandra the mirrors are so

95
00:03:54,140 --> 00:03:51,900
precisely shaped and and smoothly

96
00:03:56,210 --> 00:03:54,150
polished for Chandra that the x-ray

97
00:03:59,059 --> 00:03:56,220
images that we obtain are 10 times

98
00:04:01,759 --> 00:03:59,069
better than any previous x-ray telescope

99
00:04:03,680 --> 00:04:01,769
was able to get now as I mentioned Qian

100
00:04:05,780 --> 00:04:03,690
was flying about a thousand miles

101
00:04:08,270 --> 00:04:05,790
thousands of miles above the earth so

102
00:04:09,559 --> 00:04:08,280
sort of things not really practical the

103
00:04:12,050 --> 00:04:09,569
original hardware though is really

104
00:04:14,360 --> 00:04:12,060
working amazingly well 15 years after

105
00:04:15,949 --> 00:04:14,370
launch and our engineering team Norfolk

106
00:04:18,110 --> 00:04:15,959
Grumman has recently completed an

107
00:04:20,120 --> 00:04:18,120
analysis that suggests that at least

108
00:04:22,580 --> 00:04:20,130
another decade in orbit and perhaps even

109
00:04:24,469 --> 00:04:22,590
longer is feasible so we're looking

110
00:04:26,510 --> 00:04:24,479
forward to lots more beautiful images

111
00:04:27,450 --> 00:04:26,520
and sparkling science results from

112
00:04:30,120 --> 00:04:27,460
Chandra

113
00:04:32,189 --> 00:04:30,130

one of the questions we were asked often

114
00:04:34,920 --> 00:04:32,199
before a launch was what do we expect to

115
00:04:36,890 --> 00:04:34,930
do scientifically with Chandra we often

116
00:04:40,740 --> 00:04:36,900
gave a fairly short answer we'd say

117
00:04:43,439 --> 00:04:40,750
black holes dark matter exploding stars

118
00:04:45,029 --> 00:04:43,449
and colliding galaxies and a flippant

119
00:04:48,570 --> 00:04:45,039
sort of way we were highlighting the

120
00:04:50,820 --> 00:04:48,580
dark side and the cosmic violence in the

121
00:04:52,890 --> 00:04:50,830
universe and Chandra has come through in

122
00:04:54,900 --> 00:04:52,900
those areas and lots and lots of ones

123
00:04:58,830 --> 00:04:54,910
that we perhaps didn't even anticipate

124
00:05:00,360 --> 00:04:58,840
at the time before launch one of the

125
00:05:02,820 --> 00:05:00,370
areas that's really important for

126
00:05:07,170 --> 00:05:02,830
Chandra is exploding stars or supernovae

127
00:05:10,110 --> 00:05:07,180
and this second graphic shows a release

128
00:05:13,890 --> 00:05:10,120
that just came out in the last day or so

129
00:05:16,499 --> 00:05:13,900
of four supernova remnants the reason

130
00:05:18,990 --> 00:05:16,509
they're really fantastic to study in

131
00:05:21,120 --> 00:05:19,000
x-rays is after the explosion

132
00:05:23,219 --> 00:05:21,130
what Chandra is able to see is a blast

133
00:05:26,249 --> 00:05:23,229
wave of material firing out into space

134
00:05:28,980 --> 00:05:26,259
it's able to see superheated clouds of

135
00:05:30,870 --> 00:05:28,990
debris and ejecta things that are either

136
00:05:33,719 --> 00:05:30,880
from the star or swept up by the

137
00:05:35,310 --> 00:05:33,729
aftermath of the explosion and also the

138
00:05:36,990 --> 00:05:35,320

rotating neutron star in the middle

139
00:05:39,149 --> 00:05:37,000
which can generate tremendous amount of

140
00:05:41,730 --> 00:05:39,159
energy so there's a lot of science on

141
00:05:43,860 --> 00:05:41,740
supernova remnants three of these four

142
00:05:46,290 --> 00:05:43,870
in this image are rather young we're

143
00:05:48,719 --> 00:05:46,300
seeing them between 500 and 1,000 years

144
00:05:51,779 --> 00:05:48,729
after the explosion but the one in the

145
00:05:54,270 --> 00:05:51,789
upper center of the image is actually

146
00:05:57,149 --> 00:05:54,280
about a factor of 10 old or several

147
00:05:59,879 --> 00:05:57,159
thousand years after the explosion now

148
00:06:01,770 --> 00:05:59,889
it's one of only three in our Milky Way

149
00:06:04,230 --> 00:06:01,780
galaxy that's known to have a large

150
00:06:06,450 --> 00:06:04,240
amount of oxygen in the supernova

151
00:06:08,070 --> 00:06:06,460
remnant and of course oxygen is very

152
00:06:10,170 --> 00:06:08,080
important understanding where it comes

153
00:06:12,570 --> 00:06:10,180
from and how its dispersed is very

154
00:06:16,620 --> 00:06:12,580
important for tracing at least life as

155
00:06:18,749 --> 00:06:16,630
we know it here on earth besides taking

156
00:06:22,680 --> 00:06:18,759
pictures Chandra is always also very

157
00:06:24,600 --> 00:06:22,690
good at imaging and specific energies at

158
00:06:27,360 --> 00:06:24,610
measuring the energy of the x-rays that

159
00:06:29,460 --> 00:06:27,370
it's taking the pictures for and from

160
00:06:31,529 --> 00:06:29,470
the x-ray energy we can actually map the

161
00:06:36,620 --> 00:06:31,539
different elements so in this particular

162
00:06:40,660 --> 00:06:36,630
image of G 292 oxygen lines x-rays are

163
00:06:43,420 --> 00:06:40,670

highlighted in yellow and orange green

164
00:06:45,940 --> 00:06:43,430
response to silicon no green coarse

165
00:06:48,220 --> 00:06:45,950
plaster magnesium and blue corresponds

166
00:06:49,720 --> 00:06:48,230
to silicon sulfur so you can see how the

167
00:06:52,120 --> 00:06:49,730
different elements are distributed

168
00:06:55,600 --> 00:06:52,130
across the remnant and certainly it

169
00:06:57,520 --> 00:06:55,610
looks different in different lines if we

170
00:07:00,160 --> 00:06:57,530
look to the upper right of this image

171
00:07:03,040 --> 00:07:00,170
you see the remnant of the supernova

172
00:07:06,460 --> 00:07:03,050
explosion detected by Tycho Brahe the

173
00:07:08,320 --> 00:07:06,470
famous astronomer in 1572 besides

174
00:07:09,190 --> 00:07:08,330
studying all the debris Chandra has

175
00:07:12,310 --> 00:07:09,200
actually made a very interesting

176
00:07:14,800 --> 00:07:12,320
discovery seeing a strike light pattern

177
00:07:17,350 --> 00:07:14,810
off to one edge which is an indication

178
00:07:19,630 --> 00:07:17,360
that protons are being accelerated to

179
00:07:22,540 --> 00:07:19,640
very high energies in those regions and

180
00:07:25,120 --> 00:07:22,550
that may be the explanation or at least

181
00:07:26,970 --> 00:07:25,130
one of the major sources of mysterious

182
00:07:29,410 --> 00:07:26,980
cosmic rays showing where there

183
00:07:32,800 --> 00:07:29,420
accelerated and how they acquire their

184
00:07:36,040 --> 00:07:32,810
energy so again chandra probing yet what

185
00:07:39,090 --> 00:07:36,050
we call extreme physics now what about

186
00:07:42,970 --> 00:07:39,100
dark matter if we go to the next graphic

187
00:07:45,970 --> 00:07:42,980
this is a composite image of the famous

188
00:07:47,380 --> 00:07:45,980

bullet cluster it gets a sick name of

189
00:07:49,510 --> 00:07:47,390
the bullet cluster if you look at the

190
00:07:51,730 --> 00:07:49,520
x-rays and paint which come from Chandra

191
00:07:53,590 --> 00:07:51,740
you can see what looks like a bullet off

192
00:07:57,940 --> 00:07:53,600
to the right side of the x-ray part of

193
00:08:00,700 --> 00:07:57,950
the image now this is a composite and

194
00:08:02,590 --> 00:08:00,710
data from optical telescopes the light

195
00:08:04,480 --> 00:08:02,600
that comes from stars and galaxies has

196
00:08:07,180 --> 00:08:04,490
seen by Hubble and by ground-based

197
00:08:09,880 --> 00:08:07,190
telescope is shown in white and yellow

198
00:08:12,490 --> 00:08:09,890
and further we use what's called

199
00:08:14,890 --> 00:08:12,500
gravitational lensing we actually are

200
00:08:17,800 --> 00:08:14,900
able to use the distortion that's

201
00:08:20,260 --> 00:08:17,810
introduced in the images even further

202
00:08:22,390 --> 00:08:20,270
away galaxies galaxies that are seen

203
00:08:24,370 --> 00:08:22,400
behind the cluster when we look through

204
00:08:27,010 --> 00:08:24,380
the intervening material in the cluster

205
00:08:29,140 --> 00:08:27,020
the gravity from the cluster material

206
00:08:31,720 --> 00:08:29,150
distorts the shape of those background

207
00:08:34,150 --> 00:08:31,730
galaxies and by studying that we can

208
00:08:35,950 --> 00:08:34,160
actually map the gravity field and the

209
00:08:38,740 --> 00:08:35,960
matter that's generating the gravity in

210
00:08:40,630 --> 00:08:38,750
the cluster and that's shown in blue and

211
00:08:42,490 --> 00:08:40,640
what you should see in this image is

212
00:08:44,680 --> 00:08:42,500
that the blue most of the gravity is

213
00:08:47,530 --> 00:08:44,690

coming from material which is offset

214
00:08:49,810 --> 00:08:47,540
which is spatially located different

215
00:08:52,630 --> 00:08:49,820
from the pink which is the ordinary

216
00:08:53,600 --> 00:08:52,640
matter of the hot gas that generates the

217
00:08:56,000 --> 00:08:53,610
x-rays

218
00:08:58,550 --> 00:08:56,010
and so with Chandra and with this

219
00:09:01,280 --> 00:08:58,560
lensing data we actually are seeing this

220
00:09:03,680 --> 00:09:01,290
effect where the bullet slammed through

221
00:09:05,810 --> 00:09:03,690
the central part of the main cluster

222
00:09:09,350 --> 00:09:05,820
perhaps a hundred million years ago more

223
00:09:11,690 --> 00:09:09,360
or less and it caused the gas to slow

224
00:09:13,490 --> 00:09:11,700
down and the dark matter kept on going

225
00:09:16,340 --> 00:09:13,500
at the speed at which it was moving and

226
00:09:18,440 --> 00:09:16,350
so what we see by this separation by the

227
00:09:21,199 --> 00:09:18,450
blue being truly distinct from the pink

228
00:09:23,509 --> 00:09:21,209
is that we can't explain away or dismiss

229
00:09:25,759 --> 00:09:23,519
the possibility of dark matter by

230
00:09:28,730 --> 00:09:25,769
somehow trying to modify the laws of

231
00:09:31,730 --> 00:09:28,740
gravity as they would correspond to the

232
00:09:34,490 --> 00:09:31,740
ordinary the pink material the hot gas a

233
00:09:36,230 --> 00:09:34,500
dark matter is real and in this image we

234
00:09:38,870 --> 00:09:36,240
can see how its distinct and separate

235
00:09:39,860 --> 00:09:38,880
from the ordinary matter and with that

236
00:09:45,949 --> 00:09:39,870
I'm going to turn it over to Steve

237
00:09:48,740 --> 00:09:45,959
O'Dell ok Thank You Harvey as Harvey

238
00:09:51,019 --> 00:09:48,750

mentioned Sao and MSFC have collaborated

239
00:09:56,990 --> 00:09:51,029
for nearly 40 years on what has become

240
00:10:00,110 --> 00:09:57,000
the Chandra x-ray Observatory I came to

241
00:10:02,600 --> 00:10:00,120
MSFC in 1987 to work what was then

242
00:10:07,160 --> 00:10:02,610
called the advanced x-ray astrophysics

243
00:10:09,769 --> 00:10:07,170
facility or ax F Martin Weiskopf the

244
00:10:14,090 --> 00:10:09,779
project scientists arrived MSFC about a

245
00:10:16,910 --> 00:10:14,100
decade earlier in 1977 about one year

246
00:10:19,490 --> 00:10:16,920
after riccardo giacconi and harvey had

247
00:10:22,630 --> 00:10:19,500
convinced nasa to initiate a study that

248
00:10:25,519 --> 00:10:22,640
eventually led to the Chandra mission

249
00:10:29,360 --> 00:10:25,529
besides serving as NASA's managing

250
00:10:32,060 --> 00:10:29,370
center for the Chandra mission MSFC

251
00:10:34,430 --> 00:10:32,070
provided facilities for and coordinated

252
00:10:37,880 --> 00:10:34,440
the calibration on the ground of the

253
00:10:41,540 --> 00:10:37,890
Chandra x-ray Observatory system the

254
00:10:43,970 --> 00:10:41,550
servitor II system includes the

255
00:10:46,610 --> 00:10:43,980
high-resolution Mir assembly - focal

256
00:10:49,880 --> 00:10:46,620
plane detectors and to grading arrays

257
00:10:54,170 --> 00:10:49,890
which allow for precise determination of

258
00:10:57,380 --> 00:10:54,180
the energy of x-ray photons the first

259
00:11:00,439 --> 00:10:57,390
photo shows an aerial view of the x-ray

260
00:11:02,870 --> 00:11:00,449
calibration facility or XR CF where

261
00:11:05,000 --> 00:11:02,880
scientists and engineers from Sao MSFC

262
00:11:06,880 --> 00:11:05,010
the science instrument teams and

263
00:11:09,110 --> 00:11:06,890

industry partners

264
00:11:12,670 --> 00:11:09,120
calibrated the Chander observing system

265
00:11:16,280 --> 00:11:12,680
this calibration was a 24/7 operation

266
00:11:19,610 --> 00:11:16,290
over nearly six months starting in 1996

267
00:11:22,190 --> 00:11:19,620
December x-rays from the source building

268
00:11:24,590 --> 00:11:22,200
in the upper left travel a half a

269
00:11:27,140 --> 00:11:24,600
kilometre or 1/3 of a mile within an

270
00:11:29,170 --> 00:11:27,150
evacuated tube to a large vacuum chamber

271
00:11:32,990 --> 00:11:29,180
inside the building on the lower right

272
00:11:36,920 --> 00:11:33,000
which houses the instrument chamber the

273
00:11:39,620 --> 00:11:36,930
next photo shows the X RCS large vacuum

274
00:11:41,060 --> 00:11:39,630
chamber with the Chandra high-resolution

275
00:11:42,350 --> 00:11:41,070
mirror assembly installed near the

276
00:11:44,950 --> 00:11:42,360
source end of the chamber during

277
00:11:48,590 --> 00:11:44,960
preparations for the ground calibration

278
00:11:50,120 --> 00:11:48,600
this chamber is large enough to hold any

279
00:11:52,640 --> 00:11:50,130
payload that could be carried by the

280
00:11:54,770 --> 00:11:52,650
Space Shuttle in fact Chandra was I

281
00:11:57,680 --> 00:11:54,780
believe the longest payload ever carried

282
00:12:01,340 --> 00:11:57,690
by the space shuttle and it was carried

283
00:12:04,370 --> 00:12:01,350
by the space shuttle Columbia the SRC F

284
00:12:06,170 --> 00:12:04,380
has been used for testing x-ray and also

285
00:12:08,570 --> 00:12:06,180
visible light optical systems for

286
00:12:10,730 --> 00:12:08,580
several projects most recently for the

287
00:12:16,490 --> 00:12:10,740
cold mirrors of the James Webb Space

288
00:12:18,320 --> 00:12:16,500

Telescope to be launched in 2018 one of

289
00:12:22,720 --> 00:12:18,330
the most studied celestial objects in

290
00:12:24,740 --> 00:12:22,730
every spectral band is the Crab Nebula

291
00:12:27,860 --> 00:12:24,750
this is the remnant of a supernova

292
00:12:31,460 --> 00:12:27,870
explosion that was observed in 1054 by

293
00:12:34,250 --> 00:12:31,470
chinese astronomers in this composite

294
00:12:36,260 --> 00:12:34,260
image of the Crab Nebula red and yellow

295
00:12:38,990 --> 00:12:36,270
indicate visible emission observed by

296
00:12:42,050 --> 00:12:39,000
the Hubble Space Telescope purple

297
00:12:45,320 --> 00:12:42,060
indicates infrared emission observed by

298
00:12:48,200 --> 00:12:45,330
the Spitzer Space Telescope and the blue

299
00:12:50,110 --> 00:12:48,210
is x-ray emission observed by the

300
00:12:52,670 --> 00:12:50,120
Chandra x-ray Observatory

301
00:12:54,950 --> 00:12:52,680
now many supernova remnants are powered

302
00:12:56,540 --> 00:12:54,960
by the original explosion the Crab

303
00:12:59,390 --> 00:12:56,550
Nebula is powered primarily by the

304
00:13:02,300 --> 00:12:59,400
Pulsar a rapidly spinning highly

305
00:13:04,970 --> 00:13:02,310
magnetized neutron star this neutron

306
00:13:07,730 --> 00:13:04,980
star is the collapsed core of the pre

307
00:13:10,040 --> 00:13:07,740
supernova star and has a density similar

308
00:13:13,330 --> 00:13:10,050
to that of an atomic nucleus about a

309
00:13:16,280 --> 00:13:13,340
hundred trillion times denser than water

310
00:13:18,890 --> 00:13:16,290
the x-ray image in blue most clearly

311
00:13:20,720 --> 00:13:18,900
shows the pulsar wind nebula these

312
00:13:22,910 --> 00:13:20,730
x-rays are emitted by highly relevant

313
00:13:25,730 --> 00:13:22,920

electrons spiraling in the magnetic

314
00:13:28,220 --> 00:13:25,740
field the pulsar wind nebula emits this

315
00:13:30,889 --> 00:13:28,230
so-called synchrotron radiation across

316
00:13:34,370 --> 00:13:30,899
the electromagnetic spectrum from radio

317
00:13:37,790 --> 00:13:34,380
to infrared and visible to x-ray and

318
00:13:39,710 --> 00:13:37,800
gamma ray however as electrons emitting

319
00:13:42,439 --> 00:13:39,720
the x-rays and gamma rays lose energy

320
00:13:44,870 --> 00:13:42,449
more quickly the nebula is more compact

321
00:13:49,370 --> 00:13:44,880
at the higher energies which is why the

322
00:13:53,180 --> 00:13:49,380
blue does not fill the full nebula the

323
00:13:56,600 --> 00:13:53,190
next image is that of the x-ray emission

324
00:13:59,360 --> 00:13:56,610
alone and we see the complex structure

325
00:14:01,340 --> 00:13:59,370
of the pulsar wind nebula and I should

326
00:14:03,050 --> 00:14:01,350
emphasize that an x-ray is only Chandra

327
00:14:06,560 --> 00:14:03,060
can observe this structure because of

328
00:14:09,259 --> 00:14:06,570
its excellent resolution its ability to

329
00:14:13,210 --> 00:14:09,269
see objects that are closely spaced

330
00:14:15,800 --> 00:14:13,220
together the rapidly rotating pulsar

331
00:14:18,650 --> 00:14:15,810
which is represented by the white spot

332
00:14:20,629 --> 00:14:18,660
in the centre drives a relativistic wind

333
00:14:22,750 --> 00:14:20,639
into the surrounding nebula material

334
00:14:25,850 --> 00:14:22,760
creating a so-called termination shock

335
00:14:27,530 --> 00:14:25,860
which is the inner ring which feeds

336
00:14:29,720 --> 00:14:27,540
synchrotron emitting electrons to the

337
00:14:32,569 --> 00:14:29,730
surrounding torus and the remainder of

338
00:14:35,480 --> 00:14:32,579

the nebula adding to the complexity of

339
00:14:39,769 --> 00:14:35,490
the pulsar wind nebula is the jet or the

340
00:14:42,740 --> 00:14:39,779
tail toward the lower left the final

341
00:14:45,379 --> 00:14:42,750
graphic is an x-ray movie of the crab

342
00:14:47,240 --> 00:14:45,389
pulsar wind nebula comprised the Chandra

343
00:14:50,750 --> 00:14:47,250
images obtained over a seven-month

344
00:14:52,790 --> 00:14:50,760
period this movie illustrates that the

345
00:14:55,509 --> 00:14:52,800
structure of the pulsar wind nebula is

346
00:14:57,980 --> 00:14:55,519
not only complex but quite dynamic

347
00:15:00,410 --> 00:14:57,990
Chandra images exhibit significant

348
00:15:01,819 --> 00:15:00,420
changes near the inner ring and I can

349
00:15:04,550 --> 00:15:01,829
see think you can see the material

350
00:15:07,309 --> 00:15:04,560
moving outward on timescales of weeks

351
00:15:11,120 --> 00:15:07,319
and in the Taurus and jet on timescales

352
00:15:12,710 --> 00:15:11,130
of months to years the x-ray studies of

353
00:15:14,840 --> 00:15:12,720
the crab benefit not only from

354
00:15:17,059 --> 00:15:14,850
Chandler's exceptional imaging but also

355
00:15:21,079 --> 00:15:17,069
from the longevity of the mission as we

356
00:15:22,579 --> 00:15:21,089
are now in our 15th year next Julie will

357
00:15:26,629 --> 00:15:22,589
tell you a little about Chandra studies

358
00:15:29,600 --> 00:15:26,639
of supermassive black holes Julie thank

359
00:15:32,150 --> 00:15:29,610
you very much so I started using Chandra

360
00:15:33,990 --> 00:15:32,160
back in 2009 I when I moved to the

361
00:15:37,050 --> 00:15:34,000
University of Cambridge for my peach

362
00:15:40,140 --> 00:15:37,060
and since then Chandra has really played

363
00:15:41,760 --> 00:15:40,150

an important part in my research which

364
00:15:44,100 --> 00:15:41,770
has been to study supermassive black

365
00:15:46,500 --> 00:15:44,110
holes so the question you can ask is how

366
00:15:49,920 --> 00:15:46,510
do we actually use Chandra to study

367
00:15:51,870 --> 00:15:49,930
supermassive black holes and to actually

368
00:15:55,770 --> 00:15:51,880
if you think about it black holes as the

369
00:15:57,330 --> 00:15:55,780
name indicates our optics for which

370
00:16:00,440 --> 00:15:57,340
gravity is so strong that nothing can

371
00:16:03,630 --> 00:16:00,450
escape not even light so how can we use

372
00:16:06,060 --> 00:16:03,640
x-rays and hence Chandra to study these

373
00:16:08,180 --> 00:16:06,070
objects to show you this I'm gonna use

374
00:16:10,980 --> 00:16:08,190
the next animation which will be shown

375
00:16:13,320 --> 00:16:10,990
should be something right now so this

376
00:16:14,640 --> 00:16:13,330
animation illustrates the galaxy and

377
00:16:16,860 --> 00:16:14,650
what we're doing here is we're actually

378
00:16:19,200 --> 00:16:16,870
zooming in towards the central parts of

379
00:16:20,940 --> 00:16:19,210
this galaxy and we're zooming in is so

380
00:16:22,460 --> 00:16:20,950
much that we're gonna focus on a tiny

381
00:16:24,960 --> 00:16:22,470
region that's about a billion times

382
00:16:27,480 --> 00:16:24,970
smaller than the size of the galaxy so

383
00:16:29,880 --> 00:16:27,490
really tiny and what do we find we find

384
00:16:31,860 --> 00:16:29,890
a supermassive black hole so we think

385
00:16:34,290 --> 00:16:31,870
that all galaxies at least all the

386
00:16:37,500 --> 00:16:34,300
massive galaxies harbors one of these

387
00:16:40,280 --> 00:16:37,510
monsters at its center and so well it's

388
00:16:42,420 --> 00:16:40,290

interesting in this picture here is

389
00:16:44,700 --> 00:16:42,430
where what we're witnessing is the

390
00:16:46,620 --> 00:16:44,710
presence of an active supermassive black

391
00:16:49,020 --> 00:16:46,630
hole in the sense that it's a black hole

392
00:16:51,360 --> 00:16:49,030
pulling in matter and slowly consuming

393
00:16:53,600 --> 00:16:51,370
it and when this happens what's

394
00:16:56,460 --> 00:16:53,610
interesting is that the matter gets

395
00:16:58,590 --> 00:16:56,470
heated up to very high temperatures due

396
00:17:01,020 --> 00:16:58,600
to friction and I'm talking about about

397
00:17:03,270 --> 00:17:01,030
10 million degrees Fahrenheit so very

398
00:17:05,610 --> 00:17:03,280
very hot and one matter is this hot it's

399
00:17:07,590 --> 00:17:05,620
gonna emit a lot of x-rays so this is

400
00:17:10,110 --> 00:17:07,600
how we use x-rays to study black holes

401
00:17:12,390 --> 00:17:10,120
we use them to study the gas very near

402
00:17:15,329 --> 00:17:12,400
the black holes and this informs on

403
00:17:17,460 --> 00:17:15,339
properties of the black holes now what's

404
00:17:19,530 --> 00:17:17,470
also really interesting and that's shown

405
00:17:22,380 --> 00:17:19,540
in this animation if we zoom out a

406
00:17:25,980 --> 00:17:22,390
little bit more so what we see is a

407
00:17:28,380 --> 00:17:25,990
presence of two Jets so these Jets here

408
00:17:31,290 --> 00:17:28,390
are made of very energetic particles and

409
00:17:33,060 --> 00:17:31,300
we often detect them through their radio

410
00:17:35,160 --> 00:17:33,070
mission and what's interesting is that

411
00:17:37,080 --> 00:17:35,170
these Jets can be powerful I mean very

412
00:17:39,720 --> 00:17:37,090
very powerful and I'm gonna prove this

413
00:17:42,780 --> 00:17:39,730

to you in the next image so the next

414
00:17:45,600 --> 00:17:42,790
image what we're gonna see is an image

415
00:17:48,090 --> 00:17:45,610
of two galaxies here so the galaxies are

416
00:17:50,279 --> 00:17:48,100
traced by the pink colors

417
00:17:51,840 --> 00:17:50,289
in this image so please note that the

418
00:17:54,270 --> 00:17:51,850
color scaling here is different than the

419
00:17:54,720 --> 00:17:54,280
ones previously used pink means galaxies

420
00:17:59,220 --> 00:17:54,730
here

421
00:18:01,140 --> 00:17:59,230
means the radio emission and this is

422
00:18:03,419 --> 00:18:01,150
tracing the jet of very energetic

423
00:18:05,730 --> 00:18:03,429
particles so what's happening in this

424
00:18:08,490 --> 00:18:05,740
image is that one of the galaxies the

425
00:18:10,529 --> 00:18:08,500
one towards the lower left part of the

426
00:18:13,049 --> 00:18:10,539
image harbor is an active supermassive

427
00:18:15,360 --> 00:18:13,059
black hole this black hole is generating

428
00:18:18,270 --> 00:18:15,370
the jet that we see in the blue colors

429
00:18:21,840 --> 00:18:18,280
and the shed is so powerful that can not

430
00:18:24,450 --> 00:18:21,850
only extend beyond the host galaxy but

431
00:18:26,730 --> 00:18:24,460
it extends all the way out and crashes

432
00:18:29,640 --> 00:18:26,740
into the second galaxy so the second

433
00:18:32,159 --> 00:18:29,650
pink blob and so this is just how

434
00:18:35,220 --> 00:18:32,169
powerful the black hole can be this is

435
00:18:37,680 --> 00:18:35,230
what they can do and in the context of

436
00:18:40,380 --> 00:18:37,690
powerful black holes there's actually a

437
00:18:42,570 --> 00:18:40,390
very interesting and maybe one of the

438
00:18:45,210 --> 00:18:42,580

most unexpected discoveries Chandra ever

439
00:18:47,520 --> 00:18:45,220
made and this relates to galaxy clusters

440
00:18:52,020 --> 00:18:47,530
so in the next image what I'm going to

441
00:18:53,880 --> 00:18:52,030
show you is an optical image of MSO 735

442
00:18:57,180 --> 00:18:53,890
which is a very famous cluster of

443
00:18:59,490 --> 00:18:57,190
galaxies so clusters contain hundreds of

444
00:19:01,980 --> 00:18:59,500
thousands of galaxies and this is shown

445
00:19:03,840 --> 00:19:01,990
here in the yellow lights which traces

446
00:19:06,299 --> 00:19:03,850
the optical emission so these are all

447
00:19:08,370 --> 00:19:06,309
the galaxies but what's actually even

448
00:19:11,010 --> 00:19:08,380
more interesting is if you look at the

449
00:19:13,860 --> 00:19:11,020
same image but this time if you overlay

450
00:19:15,810 --> 00:19:13,870
the x-ray and the radio emission so this

451
00:19:19,230 --> 00:19:15,820
is gonna be the next image which will

452
00:19:22,200 --> 00:19:19,240
appear very shortly yes thank you so

453
00:19:23,850 --> 00:19:22,210
what we're seeing here is in blue we're

454
00:19:26,010 --> 00:19:23,860
seeing the x-ray emission from the

455
00:19:27,750 --> 00:19:26,020
cluster and in the pinkish colors we're

456
00:19:29,970 --> 00:19:27,760
seeing the radio so again note the

457
00:19:31,649 --> 00:19:29,980
different color scale in there and

458
00:19:33,539 --> 00:19:31,659
what's really what's really interesting

459
00:19:35,399 --> 00:19:33,549
is this image tells us two things first

460
00:19:37,799 --> 00:19:35,409
of all clusters are very x-ray bright

461
00:19:39,630 --> 00:19:37,809
sources and this is due to the hot intra

462
00:19:41,399 --> 00:19:39,640
cluster gas that lies between the

463
00:19:43,529 --> 00:19:41,409

galaxies that's what we're seeing in

464
00:19:45,810 --> 00:19:43,539
blue but what it's also seeing is this

465
00:19:48,029 --> 00:19:45,820
funny-looking radio jet in the pink

466
00:19:49,380 --> 00:19:48,039
colors what's happening is that the

467
00:19:51,960 --> 00:19:49,390
center of galaxies of the cluster

468
00:19:54,270 --> 00:19:51,970
harbours a very active supermassive

469
00:19:56,399 --> 00:19:54,280
black hole this black hole is generating

470
00:19:58,860 --> 00:19:56,409
these Jets and the shets are so powerful

471
00:20:02,070 --> 00:19:58,870
that they can literally push away the

472
00:20:04,139 --> 00:20:02,080
hot extra gas creating beautiful

473
00:20:05,730 --> 00:20:04,149
cavities in the x-ray image and they're

474
00:20:07,830 --> 00:20:05,740
filling these cavities with the radio

475
00:20:10,680 --> 00:20:07,840
meeting particles so this is what we're

476
00:20:12,149 --> 00:20:10,690
seeing now to show you another very nice

477
00:20:14,759 --> 00:20:12,159
example of this we're going to look at

478
00:20:18,060 --> 00:20:14,769
the next image which is a famous Perseus

479
00:20:20,159 --> 00:20:18,070
cluster so this cluster very famous you

480
00:20:23,220 --> 00:20:20,169
see again in the blue colors using the

481
00:20:26,490 --> 00:20:23,230
x-ray gas x-ray emitting gas and the

482
00:20:29,100 --> 00:20:26,500
pinkish blogs are the radio emission so

483
00:20:31,560 --> 00:20:29,110
again we're witnessing a cluster which

484
00:20:32,759 --> 00:20:31,570
has a central galaxy with an active

485
00:20:34,950 --> 00:20:32,769
supermassive black hole that's

486
00:20:36,840 --> 00:20:34,960
generating Jets and this is what you see

487
00:20:39,539 --> 00:20:36,850
what the pink blobs now if we looked at

488
00:20:42,210 --> 00:20:39,549

only the x-ray image so this would be

489
00:20:44,279 --> 00:20:42,220
the next image you'll see very clearly

490
00:20:47,279 --> 00:20:44,289
the cavities I was talking about so

491
00:20:49,409 --> 00:20:47,289
those are the the two of the two central

492
00:20:51,960 --> 00:20:49,419
cavity that you see around the point

493
00:20:54,570 --> 00:20:51,970
source and so these are being created by

494
00:20:56,399 --> 00:20:54,580
the jet so the jet is pushing away the

495
00:20:58,740 --> 00:20:56,409
hot x-ray emitting gas creating new

496
00:21:01,740 --> 00:20:58,750
cavities also note the cavity that's in

497
00:21:03,539 --> 00:21:01,750
the top right portion of the image so

498
00:21:05,820 --> 00:21:03,549
this is an older cavity which has

499
00:21:09,029 --> 00:21:05,830
reasonably enlight enchantra's legacy

500
00:21:10,560 --> 00:21:09,039
has really been to discover many of

501
00:21:13,560 --> 00:21:10,570
these cavities and many clusters of

502
00:21:15,330 --> 00:21:13,570
galaxies and this has really impacted

503
00:21:17,519 --> 00:21:15,340
our understanding of black holes because

504
00:21:18,930 --> 00:21:17,529
it shows that black holes have a very

505
00:21:21,180 --> 00:21:18,940
important impact on our surrounding

506
00:21:23,100 --> 00:21:21,190
meeting and many systems and that if you

507
00:21:25,289 --> 00:21:23,110
really want to understand galaxies and

508
00:21:27,419 --> 00:21:25,299
clusters you must first understand black

509
00:21:31,980 --> 00:21:27,429
holes so I'm going to leave it here and

510
00:21:32,190 --> 00:21:31,990
I'm gonna pass the mic to to Scott so go

511
00:21:35,490 --> 00:21:32,200
ahead

512
00:21:37,649 --> 00:21:35,500
alright Thank You Julie I have been part

513
00:21:40,590 --> 00:21:37,659

of the genre of science operations team

514
00:21:42,289 --> 00:21:40,600
for about 18 years my group is

515
00:21:44,450 --> 00:21:42,299
responsible for the day-to-day

516
00:21:47,460 --> 00:21:44,460
operations of the scientific instruments

517
00:21:49,830 --> 00:21:47,470
and my specific roles are pretty varied

518
00:21:51,480 --> 00:21:49,840
in addition to monitoring the scientific

519
00:21:53,759 --> 00:21:51,490
instruments I spend a lot of time

520
00:21:56,009 --> 00:21:53,769
helping observers to understand what

521
00:21:58,110 --> 00:21:56,019
Chandra can do and how to get the most

522
00:21:59,789 --> 00:21:58,120
out of their observation and I help

523
00:22:02,399 --> 00:21:59,799
organize the group of scientists from

524
00:22:04,529 --> 00:22:02,409
all over the world who evaluate proposed

525
00:22:07,590 --> 00:22:04,539
science and decide what actually gets

526
00:22:10,560 --> 00:22:07,600
done by genre firstly my scientific

527
00:22:12,090 --> 00:22:10,570
focus is on star and planet formation so

528
00:22:14,549 --> 00:22:12,100
while the previous speakers have talked

529
00:22:15,720 --> 00:22:14,559
about x-rays in terms of very extreme

530
00:22:18,690 --> 00:22:15,730
phenomena why

531
00:22:21,000 --> 00:22:18,700
at Kohl's pulsars supernovae and

532
00:22:23,040 --> 00:22:21,010
colliding galaxies and in those images

533
00:22:24,890 --> 00:22:23,050
we've been seeing some of the hottest

534
00:22:29,040 --> 00:22:24,900
objects in the universe and really

535
00:22:31,260 --> 00:22:29,050
fantastic results I concentrate on much

536
00:22:33,360 --> 00:22:31,270
colder objects and one of the most

537
00:22:34,920 --> 00:22:33,370
surprising results regards some of the

538
00:22:39,150 --> 00:22:34,930

coldest objects in the solar system

539
00:22:41,730 --> 00:22:39,160
namely comets the figure is an image of

540
00:22:44,940 --> 00:22:41,740
the comet IKEA Zhang which passed the

541
00:22:46,950 --> 00:22:44,950
earth in 2002 what we think is happening

542
00:22:49,080 --> 00:22:46,960
is that highly charged particles from

543
00:22:51,570 --> 00:22:49,090
the Sun which is off to the right about

544
00:22:53,520 --> 00:22:51,580
a hundred million miles away and stream

545
00:22:55,170 --> 00:22:53,530
out in all directions and some pass

546
00:22:57,660 --> 00:22:55,180
through the atmosphere of the comet

547
00:22:59,550 --> 00:22:57,670
which is called the coma this is

548
00:23:01,590 --> 00:22:59,560
essentially full of water molecules and

549
00:23:03,510 --> 00:23:01,600
the positively charged particles from

550
00:23:05,780 --> 00:23:03,520
the Sun are highly attracted to the

551
00:23:08,660 --> 00:23:05,790
electric electrons in the neutral water

552
00:23:11,430 --> 00:23:08,670
they transfer you might say steal

553
00:23:12,810 --> 00:23:11,440
electrons from the water as they pass

554
00:23:15,330 --> 00:23:12,820
through the comet's coma

555
00:23:17,430 --> 00:23:15,340
the stolen electrons move towards the

556
00:23:20,250 --> 00:23:17,440
center of the new particle and as they

557
00:23:22,140 --> 00:23:20,260
do this they release an x-ray of a very

558
00:23:25,050 --> 00:23:22,150
particular energy which we can measure

559
00:23:27,060 --> 00:23:25,060
and in doing this we identify the exact

560
00:23:30,270 --> 00:23:27,070
particle from the Sun that stole the

561
00:23:31,950 --> 00:23:30,280
electron from the comet and the shape in

562
00:23:34,020 --> 00:23:31,960
this image is caused by the absorption

563
00:23:36,570 --> 00:23:34,030

pattern of those particles from the Sun

564
00:23:38,610 --> 00:23:36,580
passing through the comet and that tells

565
00:23:41,220 --> 00:23:38,620
us both about the Sun and about the

566
00:23:43,110 --> 00:23:41,230
comet in addition to comets

567
00:23:45,450 --> 00:23:43,120
almost all the planets in the solar

568
00:23:48,270 --> 00:23:45,460
system from Saturn on in have been

569
00:23:50,970 --> 00:23:48,280
detected by genre along with a few moons

570
00:23:53,370 --> 00:23:50,980
and each one has a different story to

571
00:23:55,110 --> 00:23:53,380
tell about what physics is going on in

572
00:23:59,280 --> 00:23:55,120
between the Sun and the atmosphere of

573
00:24:00,900 --> 00:23:59,290
the Moon or planet and while learning

574
00:24:03,090 --> 00:24:00,910
about the Sun this way and how the

575
00:24:04,940 --> 00:24:03,100
planets interact has been very exciting

576
00:24:06,990 --> 00:24:04,950
I think one of the most tantalizing

577
00:24:08,850 --> 00:24:07,000
discoveries has come from something that

578
00:24:11,550 --> 00:24:08,860
we didn't know existed when we started

579
00:24:14,820 --> 00:24:11,560
building genre planets around other

580
00:24:16,800 --> 00:24:14,830
stars called exoplanets just like

581
00:24:18,420 --> 00:24:16,810
planets that have been discovered when

582
00:24:19,020 --> 00:24:18,430
they block optical light from other

583
00:24:22,080 --> 00:24:19,030
stars

584
00:24:26,520 --> 00:24:22,090
we've found that exoplanets can also

585
00:24:29,010 --> 00:24:26,530
block x-ray light from other stars what

586
00:24:30,990 --> 00:24:29,020
the slide is showing is both theta

587
00:24:32,700 --> 00:24:31,000
an artist conception of what the light

588
00:24:36,150 --> 00:24:32,710

changes and these other stars are

589
00:24:39,540 --> 00:24:36,160
telling us what we see is that as the

590
00:24:41,280 --> 00:24:39,550
star gets fainter well what we see is

591
00:24:44,160 --> 00:24:41,290
the star gets fainter when the planet is

592
00:24:46,710 --> 00:24:44,170
in front of it the big surprise is that

593
00:24:49,530 --> 00:24:46,720
the Eclipse which is called a transit is

594
00:24:52,530 --> 00:24:49,540
deeper and wider when viewed in x-rays

595
00:24:54,690 --> 00:24:52,540
than an optical light and what this

596
00:24:57,060 --> 00:24:54,700
means simply put is that the diameter of

597
00:24:58,680 --> 00:24:57,070
the planet x-ray wavelengths is bigger

598
00:25:01,350 --> 00:24:58,690
than the diameter of the planet at

599
00:25:03,360 --> 00:25:01,360
optical wavelengths and what that means

600
00:25:06,390 --> 00:25:03,370
is above the visible atmosphere is a

601
00:25:09,210 --> 00:25:06,400
very large very thin atmosphere pop

602
00:25:11,310 --> 00:25:09,220
again the size of the visible planet and

603
00:25:13,920 --> 00:25:11,320
what we think is going on is that the

604
00:25:16,140 --> 00:25:13,930
atmosphere at these altitudes is being

605
00:25:18,360 --> 00:25:16,150
boiled off into space by the host star

606
00:25:21,120 --> 00:25:18,370
which is only a few million miles away

607
00:25:23,310 --> 00:25:21,130
and right now there are observations

608
00:25:25,920 --> 00:25:23,320
being performed to improve the quality

609
00:25:28,770 --> 00:25:25,930
of this data and confirm this hypothesis

610
00:25:30,720 --> 00:25:28,780
and now I'm going to send it back to

611
00:25:32,750 --> 00:25:30,730
Megan who has been getting questions

612
00:25:35,490 --> 00:25:32,760
from all the various social media

613
00:25:37,560 --> 00:25:35,500

thank you Scott and thank you too Harvey

614
00:25:39,960 --> 00:25:37,570
Julie and Steve for your excellent

615
00:25:41,970 --> 00:25:39,970
presentations but just to recap before

616
00:25:43,800 --> 00:25:41,980
we go to questions and answers what this

617
00:25:46,380 --> 00:25:43,810
Google+ hang us all about we are here

618
00:25:49,080 --> 00:25:46,390
celebrating the 15th anniversary of the

619
00:25:50,670 --> 00:25:49,090
Chandra x-ray Observatory one of NASA's

620
00:25:53,190 --> 00:25:50,680
Great observatories which is currently

621
00:25:56,520 --> 00:25:53,200
in space and taking fantastic images and

622
00:25:58,650 --> 00:25:56,530
other other data from x-ray sources

623
00:26:00,180 --> 00:25:58,660
across the universe and if you are

624
00:26:02,160 --> 00:26:00,190
watching and you want to ask a question

625
00:26:04,620 --> 00:26:02,170
of our panelists today you can use the

626
00:26:07,800 --> 00:26:04,630
ask NASA hashtag or you can leave a

627
00:26:10,500 --> 00:26:07,810
comment on the Google+ events page that

628
00:26:12,240 --> 00:26:10,510
I believe a circle would through NASA so

629
00:26:14,310 --> 00:26:12,250
Queens if you're interested and you have

630
00:26:15,990 --> 00:26:14,320
an re-center question please do so but

631
00:26:18,840 --> 00:26:16,000
we do have several questions already

632
00:26:21,480 --> 00:26:18,850
including we'll start with one for

633
00:26:24,260 --> 00:26:21,490
Harvey which it says Harvey what

634
00:26:26,520 --> 00:26:24,270
observation during the whole project of

635
00:26:30,810 --> 00:26:26,530
Chander's lifetime would you consider

636
00:26:33,090 --> 00:26:30,820
the most revolutionary that's not really

637
00:26:36,320 --> 00:26:33,100
a fair question to us

638
00:26:38,370 --> 00:26:36,330

many many many of the observations

639
00:26:40,080 --> 00:26:38,380
revolutionized our thinking and our

640
00:26:42,840 --> 00:26:40,090
understanding of the systems we were

641
00:26:44,990 --> 00:26:42,850
looking at so as a case of each

642
00:26:49,380 --> 00:26:45,000
individual probably has his or her

643
00:26:51,590 --> 00:26:49,390
favorite area to me in some ways the

644
00:26:53,940 --> 00:26:51,600
most significant was the first formal

645
00:26:56,279 --> 00:26:53,950
image that we took the official first

646
00:26:59,880 --> 00:26:56,289
light image which was a short exposure

647
00:27:01,650 --> 00:26:59,890
of supernova remnant cafe and we saw

648
00:27:05,130 --> 00:27:01,660
this little dot building up in the

649
00:27:07,020 --> 00:27:05,140
center in real time on the screen it was

650
00:27:08,640 --> 00:27:07,030
a discovery and what was supposed to

651
00:27:11,039 --> 00:27:08,650
just be a beautiful picture was the

652
00:27:13,289 --> 00:27:11,049
discovery of the central object the

653
00:27:15,870 --> 00:27:13,299
neutron star presumably which formed at

654
00:27:18,149 --> 00:27:15,880
the time of the supernova explosion I

655
00:27:19,740 --> 00:27:18,159
think it was indicative to me and to

656
00:27:21,840 --> 00:27:19,750
those of us perhaps in the room at the

657
00:27:24,419 --> 00:27:21,850
time that Chandra was really going to

658
00:27:26,370 --> 00:27:24,429
push you know factors of ten or a

659
00:27:28,740 --> 00:27:26,380
hundred beyond what previous x-ray

660
00:27:31,890 --> 00:27:28,750
telescopes have been able to do so in

661
00:27:34,830 --> 00:27:31,900
some ways the setting of the tone for

662
00:27:38,159 --> 00:27:34,840
the revolution comes from that first

663
00:27:40,700 --> 00:27:38,169

light image a very excellent diplomatic

664
00:27:43,500 --> 00:27:40,710
answer I think that was it was great

665
00:27:46,860 --> 00:27:43,510
another question came in and I'll shoot

666
00:27:48,750 --> 00:27:46,870
this to Julie after 15 years of studying

667
00:27:52,799 --> 00:27:48,760
x-ray images of our universe are there

668
00:27:53,850 --> 00:27:52,809
any new areas or things to image it's an

669
00:27:56,310 --> 00:27:53,860
interesting question

670
00:27:59,730 --> 00:27:56,320
so I think that they're always be ruined

671
00:28:01,980 --> 00:27:59,740
for unexpected discoveries for objects

672
00:28:03,419 --> 00:28:01,990
that we didn't know about and we just

673
00:28:06,120 --> 00:28:03,429
take a picture and then we find

674
00:28:07,890 --> 00:28:06,130
something unexpected but I think a lot

675
00:28:10,549 --> 00:28:07,900
of the science in the next couple of

676
00:28:13,020 --> 00:28:10,559
years will come from very deep images of

677
00:28:14,909 --> 00:28:13,030
objects that we've already taken

678
00:28:16,620 --> 00:28:14,919
pictures of so for example the pursues

679
00:28:17,159 --> 00:28:16,630
cluster if we look at it very very

680
00:28:19,710 --> 00:28:17,169
deeply

681
00:28:21,480 --> 00:28:19,720
we've never reached that kind of quality

682
00:28:24,720 --> 00:28:21,490
before so we don't know what we're going

683
00:28:27,110 --> 00:28:24,730
to see so I think that's maybe where

684
00:28:29,909 --> 00:28:27,120
we're headed it's just going deeper and

685
00:28:31,620 --> 00:28:29,919
just getting the best that we can and

686
00:28:37,260 --> 00:28:31,630
finding something maybe completely

687
00:28:38,850 --> 00:28:37,270
unexpected so thank you and I have a

688
00:28:40,799 --> 00:28:38,860

question here which I'll give to Steve

689
00:28:43,020 --> 00:28:40,809
which is what was the biggest surprise

690
00:28:47,340 --> 00:28:43,030
of any during the building and testing

691
00:28:58,480 --> 00:28:54,690
biggest surprise okay I guess one thing

692
00:29:01,270 --> 00:28:58,490
that disturbed us briefly was the we had

693
00:29:03,990 --> 00:29:01,280
difficulties with opening the door of

694
00:29:06,820 --> 00:29:04,000
one of our detectors called the Asus and

695
00:29:10,090 --> 00:29:06,830
that ultimate was resolved but it was

696
00:29:11,710 --> 00:29:10,100
quite worrisome prior to launch and so

697
00:29:15,130 --> 00:29:11,720
we were all relieved on I believe as

698
00:29:16,870 --> 00:29:15,140
long as 12 of 1999 when the Asus store

699
00:29:19,860 --> 00:29:16,880
opened and we started to get the first

700
00:29:23,560 --> 00:29:19,870
x-ray photons on the CCDs

701
00:29:25,660 --> 00:29:23,570
so you didn't know between July 23rd and

702
00:29:29,560 --> 00:29:25,670
when it opened on the 12th that it would

703
00:29:32,080 --> 00:29:29,570
open right well we thought it would

704
00:29:33,520 --> 00:29:32,090
opened it had been tested but we were

705
00:29:36,910 --> 00:29:33,530
definitely really aged when it actually

706
00:29:40,990 --> 00:29:36,920
did open I think we all are thank you

707
00:29:42,190 --> 00:29:41,000
very much yes I have a question here

708
00:29:44,560 --> 00:29:42,200
what exoplanets so I'm going to give

709
00:29:47,500 --> 00:29:44,570
that one to you Scott and that says

710
00:29:50,350 --> 00:29:47,510
basically it's it's people in this

711
00:29:52,600 --> 00:29:50,360
current generation we will be able to

712
00:29:54,370 --> 00:29:52,610
see or learn about exoplanets that we

713
00:29:56,290 --> 00:29:54,380

might be able to travel to say within

714
00:29:58,300 --> 00:29:56,300
you know it would only take 10 years to

715
00:30:00,250 --> 00:29:58,310
reach or there okay I think the question

716
00:30:03,100 --> 00:30:00,260
is are there a group of exoplanets

717
00:30:05,380 --> 00:30:03,110
within 10 light years theoretically that

718
00:30:06,880 --> 00:30:05,390
we could reach a filter travel speed of

719
00:30:08,320 --> 00:30:06,890
light that we're learning about now I

720
00:30:09,370 --> 00:30:08,330
can where are the closest exoplanets

721
00:30:11,140 --> 00:30:09,380
we're learning about or are they all

722
00:30:14,020 --> 00:30:11,150
really far away and there's no chance of

723
00:30:16,870 --> 00:30:14,030
us ever in fact a lot of them are really

724
00:30:21,280 --> 00:30:16,880
really close I don't have a map inside

725
00:30:23,230 --> 00:30:21,290
my head but for Chandra's purposes we

726
00:30:24,670 --> 00:30:23,240
like them close because if they're close

727
00:30:27,040 --> 00:30:24,680
they're right and that's true for all

728
00:30:28,870 --> 00:30:27,050
telescopes so Hubble has looked at a lot

729
00:30:31,780 --> 00:30:28,880
of these the spitzer space telescope

730
00:30:34,270 --> 00:30:31,790
looks a lot of a lot of these the one

731
00:30:36,310 --> 00:30:34,280
that i happen to show i think is a

732
00:30:39,760 --> 00:30:36,320
little under a little over 30 light

733
00:30:41,440 --> 00:30:39,770
years away so it's a little further than

734
00:30:44,380 --> 00:30:41,450
you could get to in 10 years but it's

735
00:30:46,750 --> 00:30:44,390
not it's not far away relative for the

736
00:30:48,310 --> 00:30:46,760
pulsars that we saw pictures of the

737
00:30:51,010 --> 00:30:48,320
black holes that we saw pictures of

738
00:30:53,200 --> 00:30:51,020

earlier these are really in our backyard

739
00:30:55,720 --> 00:30:53,210
and I think the closest one if I

740
00:30:57,820 --> 00:30:55,730
remember correctly is about 15 or 12

741
00:30:59,980 --> 00:30:57,830
light years away that some of them are

742
00:31:03,850 --> 00:30:59,990
quite quite close because you

743
00:31:05,650 --> 00:31:03,860
want to look at bright objects too to

744
00:31:07,419 --> 00:31:05,660
see the plan go in front of it so we

745
00:31:10,810 --> 00:31:07,429
actually we look in our nearby

746
00:31:13,210 --> 00:31:10,820
neighborhood great thank you

747
00:31:14,799 --> 00:31:13,220
I am a question it just came in that

748
00:31:17,020 --> 00:31:14,809
really could go to anyone and so feel

749
00:31:19,690 --> 00:31:17,030
free for any or all of you to jump in

750
00:31:23,140 --> 00:31:19,700
what course in college should I take to

751
00:31:25,150 --> 00:31:23,150
work in work for NASA or at NASA the

752
00:31:27,549 --> 00:31:25,160
course in college I take what range I

753
00:31:29,410 --> 00:31:27,559
undergo to fit for a job at NASA so that

754
00:31:30,760 --> 00:31:29,420
mean we all know that there's a lot of

755
00:31:34,210 --> 00:31:30,770
different kinds of jobs at NASA but

756
00:31:36,040 --> 00:31:34,220
maybe and you could talk about something

757
00:31:37,299 --> 00:31:36,050
that you know a course or direction that

758
00:31:39,730 --> 00:31:37,309
you might have taken for your particular

759
00:31:41,140 --> 00:31:39,740
job what would you recommend to someone

760
00:31:46,360 --> 00:31:41,150
who want to follow in your footsteps

761
00:31:49,150 --> 00:31:46,370
so to speak no sir with Harvey so I

762
00:31:51,790 --> 00:31:49,160
think physics is very important if you

763
00:31:53,710 --> 00:31:51,800

want to do the science the astronomy and

764
00:31:56,799 --> 00:31:53,720
physics often go hand to hand different

765
00:31:59,290 --> 00:31:56,809
universities and and things have evolved

766
00:32:01,600 --> 00:31:59,300
since I was a student and so probably

767
00:32:05,040 --> 00:32:01,610
astronomy or physics are great choices

768
00:32:06,730 --> 00:32:05,050
if you want to do science there's

769
00:32:08,049 --> 00:32:06,740
certainly from an engineering

770
00:32:10,840 --> 00:32:08,059
perspective there's probably more

771
00:32:13,060 --> 00:32:10,850
opportunities to do engineering work the

772
00:32:15,730 --> 00:32:13,070
technical software work there's a

773
00:32:17,169 --> 00:32:15,740
management if you really want to make a

774
00:32:18,760 --> 00:32:17,179
difference figure out how to go to

775
00:32:20,980 --> 00:32:18,770
Congress and become one of the

776
00:32:22,870 --> 00:32:20,990
influential people that passes the laws

777
00:32:26,710 --> 00:32:22,880
that provides the funding so we can keep

778
00:32:28,270 --> 00:32:26,720
doing these projects try to throw the

779
00:32:29,620 --> 00:32:28,280
next generation of politicians I like it

780
00:32:32,049 --> 00:32:29,630
all right Julie what were you gonna say

781
00:32:34,120 --> 00:32:32,059
sorry I was just going to say definitely

782
00:32:36,070 --> 00:32:34,130
take at least one astronomy course just

783
00:32:38,799 --> 00:32:36,080
to make sure this is what you want to do

784
00:32:41,169 --> 00:32:38,809
the rest of your life if you'd like that

785
00:32:44,470 --> 00:32:41,179
course you're gonna like the career so

786
00:32:49,450 --> 00:32:44,480
when I strong to me class at least Steve

787
00:32:51,940 --> 00:32:49,460
what do you say I tell my kids do

788
00:32:53,680 --> 00:32:51,950

whatever you want do something you're

789
00:32:55,750 --> 00:32:53,690
good at something you enjoy and so if

790
00:32:57,549 --> 00:32:55,760
you can make a living here and there are

791
00:33:00,549 --> 00:32:57,559
lots of jobs within NASA that span the

792
00:33:03,430 --> 00:33:00,559
engineering science and management and

793
00:33:06,720 --> 00:33:03,440
very other various other fields so it

794
00:33:12,940 --> 00:33:06,730
depends on what the person is interested

795
00:33:13,320 --> 00:33:12,950
Scott yeah I mean self I was just going

796
00:33:16,350 --> 00:33:13,330
to say

797
00:33:18,450 --> 00:33:16,360
I myself like Harvey got my degree in

798
00:33:20,220 --> 00:33:18,460
physics and I think in terms of

799
00:33:24,270 --> 00:33:20,230
astrophysics physics and astronomy are

800
00:33:25,770 --> 00:33:24,280
pretty much essential I was I was

801
00:33:29,420 --> 00:33:25,780
basically going to say the same thing I

802
00:33:32,520 --> 00:33:29,430
got my degree in physics I got my PhD in

803
00:33:34,710 --> 00:33:32,530
astrophysics but really take the physics

804
00:33:37,410 --> 00:33:34,720
degree and from in undergraduate then

805
00:33:41,310 --> 00:33:37,420
from there you can see what does suits

806
00:33:43,590 --> 00:33:41,320
you or you know you can do in it if you

807
00:33:45,270 --> 00:33:43,600
want to work for NASA per se then it's

808
00:33:47,550 --> 00:33:45,280
probably more of an engineering thing a

809
00:33:51,230 --> 00:33:47,560
couple of us on this most of us here

810
00:33:53,430 --> 00:33:51,240
don't actually work for NASA it's the

811
00:33:55,890 --> 00:33:53,440
the people who don't work for NASA

812
00:33:58,620 --> 00:33:55,900
you'll write the proposals and give the

813
00:34:00,660 --> 00:33:58,630

science direction and then NASA provides

814
00:34:02,190 --> 00:34:00,670
the huge engineering infrastructure

815
00:34:05,100 --> 00:34:02,200
without which none of it can actually

816
00:34:06,660 --> 00:34:05,110
happen so it's a little bit goes back to

817
00:34:08,870 --> 00:34:06,670
what the question is working for NASA

818
00:34:11,700 --> 00:34:08,880
are working on space missions in general

819
00:34:14,070 --> 00:34:11,710
so I think just to add to what everybody

820
00:34:17,310 --> 00:34:14,080
said we are all doing astrophysics with

821
00:34:20,270 --> 00:34:17,320
Chandra NASA does a lot of science in

822
00:34:24,659 --> 00:34:20,280
other areas besides astrophysics so

823
00:34:26,130 --> 00:34:24,669
geology planets earth science studying

824
00:34:31,290 --> 00:34:26,140
the oceans in the atmosphere of the

825
00:34:35,730 --> 00:34:31,300
earth the study of the Sun and the solar

826
00:34:38,700 --> 00:34:35,740
wind so there's a wide variety of

827
00:34:41,370 --> 00:34:38,710
science that I think physics is still a

828
00:34:43,200 --> 00:34:41,380
good background but rather than the

829
00:34:46,350 --> 00:34:43,210
Astronomy side it's possible that

830
00:34:48,510 --> 00:34:46,360
geology or oceanography atmospheric

831
00:34:52,080 --> 00:34:48,520
sciences they all are things that NASA

832
00:34:53,520 --> 00:34:52,090
is very engaged and involved and so it's

833
00:34:55,050 --> 00:34:53,530
a little bit broader than just the

834
00:34:58,440 --> 00:34:55,060
astronomy and astrophysics we were

835
00:35:00,540 --> 00:34:58,450
talking about great thank you everyone I

836
00:35:02,460 --> 00:35:00,550
have one question I came in that I

837
00:35:06,270 --> 00:35:02,470
showed I know the answer to and I don't

838
00:35:08,070 --> 00:35:06,280

know it too but I'll throw it out there

839
00:35:09,990 --> 00:35:08,080
and see if we have any takers

840
00:35:11,670 --> 00:35:10,000
has there been any images from Chandra

841
00:35:18,330 --> 00:35:11,680
that completely defied the laws of

842
00:35:22,650 --> 00:35:18,340
physics no okay easy answer High

843
00:35:26,730 --> 00:35:22,660
Definition yeah that's a double check

844
00:35:29,430 --> 00:35:26,740
and this was specifically for Harvey

845
00:35:32,510 --> 00:35:29,440
you can also add to it what is the next

846
00:35:35,820 --> 00:35:32,520
step for x-ray astronomy after Chandra

847
00:35:38,370 --> 00:35:35,830
so the next step for x-ray after Chandra

848
00:35:40,980 --> 00:35:38,380
so the immediate step is to keep Chandra

849
00:35:43,050 --> 00:35:40,990
in good shape good health and keep it

850
00:35:45,240 --> 00:35:43,060
working and I mentioned in my remarks

851
00:35:47,400 --> 00:35:45,250
starting out that the projection is at

852
00:35:49,859 --> 00:35:47,410
least for another decade and that's in

853
00:35:51,720 --> 00:35:49,869
part because there are no telescopes on

854
00:35:53,910 --> 00:35:51,730
the drawing boards in the US or any

855
00:35:56,130 --> 00:35:53,920
place else in the world and have the

856
00:35:59,430 --> 00:35:56,140
imaging capability that Chandra brings

857
00:36:01,140 --> 00:35:59,440
our colleagues in Europe are working or

858
00:36:03,720 --> 00:36:01,150
just at the early stages of working on a

859
00:36:07,109 --> 00:36:03,730
project called Athena which will have a

860
00:36:09,660 --> 00:36:07,119
large collecting area but will not make

861
00:36:12,329 --> 00:36:09,670
pictures or have the full sensitivity of

862
00:36:14,130 --> 00:36:12,339
Chandra in the u.s. we've been studying

863
00:36:16,200 --> 00:36:14,140

yet Marshall at Goddard Space Flight

864
00:36:18,780 --> 00:36:16,210
Center that here at the Smithsonian a

865
00:36:21,270 --> 00:36:18,790
few other places how to make mirrors

866
00:36:24,089 --> 00:36:21,280
that are just as good as Chandra but for

867
00:36:26,880 --> 00:36:24,099
the same masses chamber perhaps 30 or 50

868
00:36:28,770 --> 00:36:26,890
or even 100 times the collecting area so

869
00:36:30,810 --> 00:36:28,780
we're envisioning something just as good

870
00:36:33,690 --> 00:36:30,820
in terms of the image quality as Chandra

871
00:36:36,780 --> 00:36:33,700
but able to see by collecting more

872
00:36:39,329 --> 00:36:36,790
x-rays by being bigger see things that

873
00:36:41,070 --> 00:36:39,339
are either fainter or further away are

874
00:36:42,810 --> 00:36:41,080
the things that Julie was talking about

875
00:36:46,130 --> 00:36:42,820
where we would need longer and longer

876
00:36:48,570 --> 00:36:46,140
exposures the deepest Chandra exposure

877
00:36:51,750 --> 00:36:48,580
and what's called the Chandra Deep Field

878
00:36:53,940 --> 00:36:51,760
south is four million seconds worth of

879
00:36:56,280 --> 00:36:53,950
exposure time and it took us between two

880
00:36:57,780 --> 00:36:56,290
and three months to accumulate that with

881
00:37:01,140 --> 00:36:57,790
this new mission that we've just begun

882
00:37:03,900 --> 00:37:01,150
to study called smart X which stands for

883
00:37:06,450 --> 00:37:03,910
square meter arc second telescope for

884
00:37:08,490 --> 00:37:06,460
x-rays we could do that thing that took

885
00:37:10,710 --> 00:37:08,500
us two and a half months say we could do

886
00:37:12,720 --> 00:37:10,720
that in a single day so you can imagine

887
00:37:14,940 --> 00:37:12,730
we could do a lot more pieces of the sky

888
00:37:17,130 --> 00:37:14,950

we could do more objects we could go

889
00:37:19,050 --> 00:37:17,140
fainter we could do better so all of us

890
00:37:22,200 --> 00:37:19,060
are working on the technology and the

891
00:37:24,570 --> 00:37:22,210
science case for such a mission if all

892
00:37:29,010 --> 00:37:24,580
went very well we could conceivably

893
00:37:31,320 --> 00:37:29,020
compete for the top slot in the next

894
00:37:33,750 --> 00:37:31,330
decade there's usually review done every

895
00:37:36,300 --> 00:37:33,760
10 years that tries to say what the next

896
00:37:38,370 --> 00:37:36,310
mission ought to be so the next x-ray

897
00:37:40,510 --> 00:37:38,380
mission that I think is a true successor

898
00:37:43,090 --> 00:37:40,520
to Chandra is something along

899
00:37:46,420 --> 00:37:43,100
lines of smart X conceivably could fly

900
00:37:47,860 --> 00:37:46,430
by the 2030 timeframe which is a good

901
00:37:50,500 --> 00:37:47,870
reason to keep Chandler going for

902
00:37:52,600 --> 00:37:50,510
another 10 or 15 years right right and

903
00:37:54,310 --> 00:37:52,610
along those Lots there's a there was a

904
00:37:57,400 --> 00:37:54,320
follow-up question or a real a question

905
00:37:59,530 --> 00:37:57,410
I should say and so is the real next

906
00:38:01,120 --> 00:37:59,540
what's the main next major advancement

907
00:38:02,950 --> 00:38:01,130
is that the mirror isn't something else

908
00:38:04,030 --> 00:38:02,960
that the next generation of x-ray

909
00:38:06,400 --> 00:38:04,040
telescope

910
00:38:08,140 --> 00:38:06,410
the biggest hurdle I should say is that

911
00:38:10,390 --> 00:38:08,150
the mirror is it other things it

912
00:38:13,090 --> 00:38:10,400
detectors to make a mirror that's a very

913
00:38:16,090 --> 00:38:13,100

lightweight and high-performing mirror

914
00:38:17,920 --> 00:38:16,100
so the chandra mirrors are the pieces of

915
00:38:20,620 --> 00:38:17,930
glass that comprised those mirrors were

916
00:38:23,440 --> 00:38:20,630
nearly one inch thick and so when you

917
00:38:25,390 --> 00:38:23,450
put several of them together you come up

918
00:38:27,550 --> 00:38:25,400
to a few thousand kilograms which was

919
00:38:29,740 --> 00:38:27,560
the amount of mass available to watch

920
00:38:32,620 --> 00:38:29,750
from those mirrors the mirrors that were

921
00:38:37,540 --> 00:38:32,630
looking at now the thickness of the

922
00:38:40,300 --> 00:38:37,550
glass is measured in fractions of a

923
00:38:42,310 --> 00:38:40,310
millimeter so you know something closer

924
00:38:47,440 --> 00:38:42,320
to a hundredth of an inch or 50 of them

925
00:38:49,720 --> 00:38:47,450
an inch and to make the flimsy pieces of

926
00:38:52,120 --> 00:38:49,730
glass or whatever material you choose to

927
00:38:54,340 --> 00:38:52,130
use to make them actually perform with

928
00:38:55,480 --> 00:38:54,350
high precision is both a science and an

929
00:38:57,220 --> 00:38:55,490
engineering challenge

930
00:39:00,820 --> 00:38:57,230
there are definitely advances in the

931
00:39:02,560 --> 00:39:00,830
detectors to have detectors with very

932
00:39:05,860 --> 00:39:02,570
high performance over the full energy

933
00:39:09,160 --> 00:39:05,870
band to get both high quality spectrum

934
00:39:14,080 --> 00:39:09,170
and good imaging so there are numbers of

935
00:39:16,360 --> 00:39:14,090
different technology research projects

936
00:39:18,220 --> 00:39:16,370
on the detectors as well but I think the

937
00:39:21,250 --> 00:39:18,230
single most challenging is to make this

938
00:39:23,170 --> 00:39:21,260

next generation of x-ray mirrors which

939
00:39:27,370 --> 00:39:23,180
is really going to be a technical

940
00:39:29,350 --> 00:39:27,380
breakthrough right yeah you said a great

941
00:39:31,060 --> 00:39:29,360
reason to get another 15 years at a

942
00:39:33,310 --> 00:39:31,070
Chandra because there's so much we can

943
00:39:34,870 --> 00:39:33,320
do I mean this next question is about

944
00:39:37,900 --> 00:39:34,880
stellar-mass black holes and I'm gonna

945
00:39:40,000 --> 00:39:37,910
throw to you Julie but it basically is

946
00:39:41,860 --> 00:39:40,010
asking how many stellar-mass black holes

947
00:39:42,940 --> 00:39:41,870
have we found with Chandra but before

948
00:39:44,500 --> 00:39:42,950
you answer that maybe you could just

949
00:39:47,410 --> 00:39:44,510
explain how there are different sizes of

950
00:39:49,270 --> 00:39:47,420
black holes that we know about yeah so I

951
00:39:52,060 --> 00:39:49,280
was talking mostly about supermassive

952
00:39:54,040 --> 00:39:52,070
black holes so the really big ones that

953
00:39:56,080 --> 00:39:54,050
a massive at least a million times the

954
00:39:58,810 --> 00:39:56,090
mass of our Sun so very big massive

955
00:40:01,240 --> 00:39:58,820
black holes but they're actually very

956
00:40:03,190 --> 00:40:01,250
different kind of black holes which we

957
00:40:05,110 --> 00:40:03,200
call the stellar-mass black holes so

958
00:40:07,900 --> 00:40:05,120
these are a couple times the mass of our

959
00:40:11,830 --> 00:40:07,910
Sun up to let's say 20 times the mass of

960
00:40:16,270 --> 00:40:11,840
our Sun and we know so far of maybe 30

961
00:40:18,010 --> 00:40:16,280
systems in our Milky Way and some of

962
00:40:20,650 --> 00:40:18,020
which have been found through their

963
00:40:23,620 --> 00:40:20,660

x-ray emission so the way it works for

964
00:40:25,450 --> 00:40:23,630
those small black holes we think that

965
00:40:26,920 --> 00:40:25,460
they come from we know that they come

966
00:40:29,050 --> 00:40:26,930
from the deck of stars

967
00:40:30,940 --> 00:40:29,060
this is very massive stars and what

968
00:40:34,120 --> 00:40:30,950
happened to that sometimes these stars

969
00:40:36,190 --> 00:40:34,130
are gonna be in binary systems so

970
00:40:38,140 --> 00:40:36,200
there's gonna be this star that just

971
00:40:39,850 --> 00:40:38,150
blew up in supernovae created a black

972
00:40:42,640 --> 00:40:39,860
hole and then you have another star

973
00:40:45,670 --> 00:40:42,650
that's orbiting around it and sometimes

974
00:40:47,770 --> 00:40:45,680
these two can get so close that's the

975
00:40:50,800 --> 00:40:47,780
gravity of the black hole distorts the

976
00:40:52,660 --> 00:40:50,810
second of the star and the matter of

977
00:40:55,690 --> 00:40:52,670
this star slowly get secreted onto the

978
00:40:57,130 --> 00:40:55,700
black hole and in the same case as what

979
00:40:59,650 --> 00:40:57,140
we saw with supermassive black holes

980
00:40:59,980 --> 00:40:59,660
when a black hole starts accreting

981
00:41:03,580 --> 00:40:59,990
matter

982
00:41:05,940 --> 00:41:03,590
very high temperatures and it's going to

983
00:41:08,470 --> 00:41:05,950
be a lot of x-rays so we can find these

984
00:41:12,040 --> 00:41:08,480
stellar-mass black holes in these binary

985
00:41:16,570 --> 00:41:12,050
systems either x-ray emission and so we

986
00:41:19,030 --> 00:41:16,580
know of about 30 maybe 40 so far still

987
00:41:21,250 --> 00:41:19,040
some to be confirmed but there's a lot

988
00:41:22,600 --> 00:41:21,260

of progress there the great thing about

989
00:41:25,240 --> 00:41:22,610
these systems is that they're much

990
00:41:28,210 --> 00:41:25,250
smaller so they evolve much more quickly

991
00:41:31,900 --> 00:41:28,220
and so we can see them changing in our

992
00:41:34,720 --> 00:41:31,910
lifetime so that's very interesting but

993
00:41:36,670 --> 00:41:34,730
yes I think I hope that answers the

994
00:41:38,500 --> 00:41:36,680
question no I think that did thank you

995
00:41:40,210 --> 00:41:38,510
very much and then I just want to

996
00:41:42,340 --> 00:41:40,220
mention there is an elusive maybe middle

997
00:41:44,500 --> 00:41:42,350
category of black holes is still being

998
00:41:45,310 --> 00:41:44,510
discussed but not proven called well

999
00:41:46,690 --> 00:41:45,320
mister arm is called them

1000
00:41:49,390 --> 00:41:46,700
intermediate-mass black holes but that's

1001
00:41:52,360 --> 00:41:49,400
a another story for another day another

1002
00:41:54,460 --> 00:41:52,370
question came in and I'll throw this to

1003
00:41:56,740 --> 00:41:54,470
Steve is there anything about the

1004
00:42:04,090 --> 00:41:56,750
telescope you've changed or improve if

1005
00:42:05,620 --> 00:42:04,100
you cook well obviously uh forget

1006
00:42:07,210 --> 00:42:05,630
even better resolution that would be

1007
00:42:09,370 --> 00:42:07,220
wonderful

1008
00:42:11,740 --> 00:42:09,380
the main thing however as Harvey

1009
00:42:14,320 --> 00:42:11,750
mentioned is the the wait that since the

1010
00:42:17,320 --> 00:42:14,330
mirrors are an inch thick it's very

1011
00:42:19,570 --> 00:42:17,330
difficult to go to higher mass or higher

1012
00:42:20,830 --> 00:42:19,580
a collecting area without going to

1013
00:42:24,280 --> 00:42:20,840

thinner mirrors and that's the big

1014
00:42:26,680 --> 00:42:24,290
challenge that as Harvey said Goddard

1015
00:42:30,790 --> 00:42:26,690
Marshall and Sao and a few other places

1016
00:42:32,650 --> 00:42:30,800
are working on now and I think making

1017
00:42:34,120 --> 00:42:32,660
them lighter would be the best thing and

1018
00:42:35,800 --> 00:42:34,130
could you just quickly explain why you

1019
00:42:37,600 --> 00:42:35,810
want lighter is it because because we

1020
00:42:40,150 --> 00:42:37,610
have to lift it into the air and into

1021
00:42:42,310 --> 00:42:40,160
the space and so it's yeah it's right

1022
00:42:45,010 --> 00:42:42,320
with we have to be able to launch it on

1023
00:42:46,840 --> 00:42:45,020
a rocket and get it into orbit to get

1024
00:42:49,930 --> 00:42:46,850
above the Earth's atmosphere to do x-ray

1025
00:42:52,720 --> 00:42:49,940
astronomy and so with lift capabilities

1026
00:42:57,490 --> 00:42:52,730
of various rockets it's necessary to

1027
00:42:59,560 --> 00:42:57,500
keep the total mass below some limit and

1028
00:43:01,060 --> 00:42:59,570
that means trying to get more if we want

1029
00:43:02,880 --> 00:43:01,070
to increase the area of Chandra by a

1030
00:43:05,200 --> 00:43:02,890
factor of 30 we pretty much have to

1031
00:43:07,030 --> 00:43:05,210
decrease the thickness by about a factor

1032
00:43:09,370 --> 00:43:07,040
of 30 of the mirrors and when mirrors

1033
00:43:10,870 --> 00:43:09,380
get that then they're quite flimsy so

1034
00:43:12,870 --> 00:43:10,880
how does one hold them and that's one of

1035
00:43:16,810 --> 00:43:12,880
the issues that we're addressing

1036
00:43:19,210 --> 00:43:16,820
collectively thank you I have a question

1037
00:43:21,850 --> 00:43:19,220
here that I know if you can answer it

1038
00:43:23,530 --> 00:43:21,860

which is if you know it which I think

1039
00:43:30,640 --> 00:43:23,540
you do where did the name Chandra come

1040
00:43:34,930 --> 00:43:30,650
from there was a contest that was run

1041
00:43:38,440 --> 00:43:34,940
and advertised worldwide that I think we

1042
00:43:41,530 --> 00:43:38,450
had over 6,000 entries with different

1043
00:43:44,470 --> 00:43:41,540
possible names suggested the people were

1044
00:43:46,240 --> 00:43:44,480
asked to write a paragraph explaining

1045
00:43:52,330 --> 00:43:46,250
why the name they were suggesting might

1046
00:43:54,250 --> 00:43:52,340
be a good name and wrote rankin for

1047
00:43:57,070 --> 00:43:54,260
example was suggested because it was the

1048
00:43:58,690 --> 00:43:57,080
person who discovered x-rays but the

1049
00:44:00,790 --> 00:43:58,700
Germans had already flown a satellite

1050
00:44:03,340 --> 00:44:00,800
satellite called the roentgen satellite

1051
00:44:05,230 --> 00:44:03,350
rosette so even though that name may

1052
00:44:07,710 --> 00:44:05,240
have been the one suggested the most in

1053
00:44:10,900 --> 00:44:07,720
the contest it was essentially not

1054
00:44:13,330 --> 00:44:10,910
eligible as a winner

1055
00:44:15,430 --> 00:44:13,340
the name Chandra was suggested by at

1056
00:44:16,660 --> 00:44:15,440
least a couple hundred of the 6,000

1057
00:44:19,769 --> 00:44:16,670
entries and we and

1058
00:44:24,210 --> 00:44:19,779
having to use the essays as tiebreakers

1059
00:44:30,130 --> 00:44:24,220
but Chandrasekhar was a very eminent

1060
00:44:36,670 --> 00:44:30,140
Indian born American astrophysicist who

1061
00:44:38,740 --> 00:44:36,680
as a I guess predock or going into his

1062
00:44:41,819 --> 00:44:38,750
doctoral studies did calculations

1063
00:44:45,519 --> 00:44:41,829

including special relativity and quantum

1064
00:44:48,430 --> 00:44:45,529
mechanics and basically calculated that

1065
00:44:50,160 --> 00:44:48,440
a white dwarf star could have a maximum

1066
00:44:53,200 --> 00:44:50,170
mass which is the so called

1067
00:44:55,599 --> 00:44:53,210
Chandrasekhar limit if you got beyond

1068
00:44:57,640 --> 00:44:55,609
that you get into the realm of four star

1069
00:44:59,890 --> 00:44:57,650
collapses and what collapses is more

1070
00:45:02,890 --> 00:44:59,900
than about one and a half times the mass

1071
00:45:05,710 --> 00:45:02,900
of our Sun we now know you make neutron

1072
00:45:07,990 --> 00:45:05,720
stars and black holes so the kinds of

1073
00:45:10,150 --> 00:45:08,000
things that are pretty bright x-ray

1074
00:45:12,430 --> 00:45:10,160
sources the things that we're interested

1075
00:45:14,470 --> 00:45:12,440
in studying were things that came out

1076
00:45:18,569 --> 00:45:14,480
well they didn't come out but there were

1077
00:45:21,339 --> 00:45:18,579
things that Chan was calculations

1078
00:45:23,380 --> 00:45:21,349
eventually led to us beginning to think

1079
00:45:26,829 --> 00:45:23,390
about those kinds of objects and and

1080
00:45:29,160 --> 00:45:26,839
other scientists as well Chandra was his

1081
00:45:32,710 --> 00:45:29,170
nickname for for Chandra Sekhar

1082
00:45:34,690 --> 00:45:32,720
apparently in the Sanskrit language it

1083
00:45:37,539 --> 00:45:34,700
also means luminous and his used to

1084
00:45:40,390 --> 00:45:37,549
often describe the moon so it has a an

1085
00:45:42,160 --> 00:45:40,400
astronomical connotation as well the

1086
00:45:43,029 --> 00:45:42,170
contest was actually won by a high

1087
00:45:44,589 --> 00:45:43,039
school student

1088
00:45:46,660 --> 00:45:44,599

there were two winners selected one was

1089
00:45:49,329 --> 00:45:46,670
a high school student the other was a

1090
00:45:51,190 --> 00:45:49,339
teacher and their prize for winning

1091
00:45:53,140 --> 00:45:51,200
besides becoming famous of course for

1092
00:45:57,940 --> 00:45:53,150
Navy Chandra was they got to come to the

1093
00:46:01,329 --> 00:45:57,950
launch very exciting I think it's been a

1094
00:46:03,999 --> 00:46:01,339
great name I've got a question here that

1095
00:46:08,710 --> 00:46:04,009
again I will I'll see who wants to

1096
00:46:12,640 --> 00:46:08,720
answer it um is I'm sorry

1097
00:46:15,880 --> 00:46:12,650
got a company I think that this person

1098
00:46:18,970 --> 00:46:15,890
is referring to the recent advances that

1099
00:46:20,380 --> 00:46:18,980
were made with a bicep results it

1100
00:46:23,319 --> 00:46:20,390
basically says based on the images

1101
00:46:24,700 --> 00:46:23,329
Chandra has gathered does it have any

1102
00:46:25,749 --> 00:46:24,710
impact on the theories for the beginning

1103
00:46:29,109 --> 00:46:25,759
of the universe I think they're asking

1104
00:46:30,880 --> 00:46:29,119
is there anything to do with contain or

1105
00:46:33,549 --> 00:46:30,890
contributing to the theory of

1106
00:46:41,920 --> 00:46:33,559
you know the waste results or is that a

1107
00:46:44,470 --> 00:46:41,930
totally separate realm any takers so in

1108
00:46:46,809 --> 00:46:44,480
terms of inflation I'm not sure but in

1109
00:46:49,630 --> 00:46:46,819
terms of our universe and how our

1110
00:46:52,210 --> 00:46:49,640
universe is accelerating and expanding

1111
00:46:55,029 --> 00:46:52,220
it can do this and you can do this with

1112
00:46:57,490 --> 00:46:55,039
clusters of galaxies and it does this by

1113
00:47:00,809 --> 00:46:57,500

essentially finding clusters that are

1114
00:47:03,130 --> 00:47:00,819
very very far and the number of clusters

1115
00:47:05,920 --> 00:47:03,140
the masses they have will depend

1116
00:47:07,690 --> 00:47:05,930
directly on how the universe has

1117
00:47:09,789 --> 00:47:07,700
expanded and accelerated and so you can

1118
00:47:12,130 --> 00:47:09,799
get constraints using that so it's not

1119
00:47:14,799 --> 00:47:12,140
really inflation but it's still you're

1120
00:47:16,539 --> 00:47:14,809
getting the bigger picture from doing

1121
00:47:18,160 --> 00:47:16,549
that and so again clusters are very

1122
00:47:20,500 --> 00:47:18,170
bright in the x-ray and this is white

1123
00:47:21,309 --> 00:47:20,510
and right it's very useful for that and

1124
00:47:22,420 --> 00:47:21,319
that actually brings up a good point

1125
00:47:23,770 --> 00:47:22,430
that we haven't I don't think we've

1126
00:47:26,079 --> 00:47:23,780
touched on yet which is that Chandra is

1127
00:47:28,390 --> 00:47:26,089
really very important in the discussion

1128
00:47:30,910 --> 00:47:28,400
about dark energy and investigating what

1129
00:47:33,309 --> 00:47:30,920
dark energy you know how it behaves and

1130
00:47:35,529 --> 00:47:33,319
how it's affected the universe over you

1131
00:47:36,700 --> 00:47:35,539
know the course of the universe so yeah

1132
00:47:38,289 --> 00:47:36,710
that's a very important talk with them

1133
00:47:40,539 --> 00:47:38,299
I'm glad actually you mentioned that

1134
00:47:42,250 --> 00:47:40,549
because it's something traders is

1135
00:47:45,220 --> 00:47:42,260
critical in doing and we haven't talked

1136
00:47:52,660 --> 00:47:45,230
about that yet otherwise when to Scott

1137
00:47:57,670 --> 00:47:52,670
and that is go it's basically a question

1138
00:47:59,349 --> 00:47:57,680

of how does Chandra affect people in

1139
00:48:02,289 --> 00:47:59,359
their day to day life is there some

1140
00:48:04,900 --> 00:48:02,299
technology that impacts them based on

1141
00:48:06,880 --> 00:48:04,910
Chandra or is there some piece of

1142
00:48:09,220 --> 00:48:06,890
knowledge that you know it doesn't

1143
00:48:10,809 --> 00:48:09,230
probably you know impact on a day to day

1144
00:48:14,049 --> 00:48:10,819
decision but this sort of what's the

1145
00:48:16,240 --> 00:48:14,059
sort of takeaway for the average person

1146
00:48:18,640 --> 00:48:16,250
who may or may not be necessarily

1147
00:48:20,319 --> 00:48:18,650
interested in the finer details of

1148
00:48:22,359 --> 00:48:20,329
astrophysics what's their takeaway

1149
00:48:24,339 --> 00:48:22,369
message that people can can think about

1150
00:48:26,680 --> 00:48:24,349
when we think of Chandra well I think

1151
00:48:29,410 --> 00:48:26,690
the takeaway and this is this is a

1152
00:48:31,059 --> 00:48:29,420
personal take I think everyone else on

1153
00:48:36,339 --> 00:48:31,069
the panel all the different version of

1154
00:48:38,069 --> 00:48:36,349
it but we we now have a reality of black

1155
00:48:41,890 --> 00:48:38,079
holes there were sort of science fiction

1156
00:48:44,020 --> 00:48:41,900
concepts in the 60s and 70s we have a

1157
00:48:47,530 --> 00:48:44,030
visit we we can see

1158
00:48:48,940 --> 00:48:47,540
what supernova remnants really look like

1159
00:48:51,580 --> 00:48:48,950
really how they act

1160
00:48:53,230 --> 00:48:51,590
my favorite single image from genre and

1161
00:48:55,060 --> 00:48:53,240
I know this was a question earlier it

1162
00:48:58,750 --> 00:48:55,070
wasn't me it was the one that Steve

1163
00:49:00,580 --> 00:48:58,760

showed of the crab and the reason was

1164
00:49:03,220 --> 00:49:00,590
when I looked at that picture the first

1165
00:49:06,520 --> 00:49:03,230
time when it was taken I said that's a

1166
00:49:08,530 --> 00:49:06,530
drawing right I mean you see the the

1167
00:49:10,660 --> 00:49:08,540
swirling the stuff that's swirling

1168
00:49:13,180 --> 00:49:10,670
around the pulsar and the Jets shooting

1169
00:49:21,190 --> 00:49:13,190
out and the skimming and the the Rings

1170
00:49:24,010 --> 00:49:21,200
and it's not somebody's imagination what

1171
00:49:29,890 --> 00:49:24,020
genre has given us is that's reality

1172
00:49:32,620 --> 00:49:29,900
that's really what's out there and no we

1173
00:49:36,190 --> 00:49:32,630
can't go to a black hole and we can't go

1174
00:49:38,820 --> 00:49:36,200
to a pulsar and we can't even go to the

1175
00:49:41,740 --> 00:49:38,830
nearest exoplanet buts

1176
00:49:44,410 --> 00:49:41,750
satellites like genre can take us there

1177
00:49:46,990 --> 00:49:44,420
and show us exactly what it looks like

1178
00:49:49,480 --> 00:49:47,000
it looks like we're steering staring out

1179
00:49:51,100 --> 00:49:49,490
a port of the Starship Enterprise but no

1180
00:49:53,470 --> 00:49:51,110
that's really what we're seeing from

1181
00:49:56,650 --> 00:49:53,480
Earth because we have this spectacular

1182
00:49:58,990 --> 00:49:56,660
telescope and we'll brought more broadly

1183
00:50:02,800 --> 00:49:59,000
speaking NASA's fleet of spectacular

1184
00:50:05,620 --> 00:50:02,810
telescopes and they show us that this is

1185
00:50:08,350 --> 00:50:05,630
the universe we live in and we're just a

1186
00:50:11,890 --> 00:50:08,360
small part of it but we can take in all

1187
00:50:13,870 --> 00:50:11,900
of it so that's like I said personal

1188
00:50:15,790 --> 00:50:13,880

tape I could ask more questions and I

1189
00:50:18,790 --> 00:50:15,800
think that's a beautiful way to wrap up

1190
00:50:20,620 --> 00:50:18,800
this Google+ hangout I do want to take a

1191
00:50:23,260 --> 00:50:20,630
moment to thank all of the panelists who

1192
00:50:25,780 --> 00:50:23,270
came here today and went their expertise

1193
00:50:27,220 --> 00:50:25,790
and experience to describe the very

1194
00:50:28,300 --> 00:50:27,230
exciting things that chanters been doing

1195
00:50:30,670 --> 00:50:28,310
for the past 15 years

1196
00:50:33,460 --> 00:50:30,680
I want to thank NASA social media for

1197
00:50:34,780 --> 00:50:33,470
helping set this event up and if there

1198
00:50:36,640 --> 00:50:34,790
any further questions I'm sure you can

1199
00:50:39,130 --> 00:50:36,650
still continue to ask the essence we

1200
00:50:41,160 --> 00:50:39,140
have an ask NASA hashtag and we will do

1201
00:50:43,120 --> 00:50:41,170
our best to answer them as they come in

1202
00:50:45,340 --> 00:50:43,130
there any wise comments and they would

1203
00:50:49,330 --> 00:50:45,350
like to make or otherwise and just sign

1204
00:50:51,370 --> 00:50:49,340
up for today we're good

1205
00:50:53,050 --> 00:50:51,380
all right everyone well thank you so