1
00:00:09,030 --> 00:00:05,670
black holes are the strongest test of

2
00:00:10,870 --> 00:00:09,040
what the theory of gravity really is

3
00:00:13,270 --> 00:00:10,880
space is just bent and warped and

4
00:00:14,950 --> 00:00:13,280
twisted in some incredibly complex way

5
00:00:17,029 --> 00:00:14,960
and if one could only understand that

6
00:00:18,950 --> 00:00:17,039
one would have a fundamental insight

7
00:00:20,710 --> 00:00:18,960
into the theory of gravity

8
00:00:23,429 --> 00:00:20,720
in the past five years our knowledge of

9
00:00:25,590 --> 00:00:23,439
black holes has really exploded

10
00:00:27,269 --> 00:00:25,600
by using space-based and ground-based

11
00:00:29,669 --> 00:00:27,279
telescopes covering the full

12
00:00:31,269 --> 00:00:29,679
electromagnetic spectrum astronomers

13
00:00:32,790 --> 00:00:31,279

have found that black holes are

14
00:00:34,950 --> 00:00:32,800
everywhere

15
00:00:36,549 --> 00:00:34,960
they come in a variety of sizes and they

16
00:00:38,069 --> 00:00:36,559
are integral to the formation of

17
00:00:40,069 --> 00:00:38,079
galaxies

18
00:00:42,470 --> 00:00:40,079
one way to find a black hole is to look

19
00:00:44,630 --> 00:00:42,480
for x-rays that are produced by matter

20
00:00:46,229 --> 00:00:44,640
caught up in its violent and extreme

21
00:00:48,310 --> 00:00:46,239
environment

22
00:00:50,549 --> 00:00:48,320
in fact we are extremely close to

23
00:00:54,470 --> 00:00:50,559
looking at the very edge of a black hole

24
00:00:56,950 --> 00:00:54,480
something einstein never imagined

25
00:00:59,110 --> 00:00:56,960
what happens to matter and energy as it

26
00:01:01,270 --> 00:00:59,120
moves closer to a black hole

27
00:01:02,709 --> 00:01:01,280
and crosses the event horizon

28
00:01:04,310 --> 00:01:02,719
the theoretical border from which

29
00:01:06,870 --> 00:01:04,320
nothing can escape

30
00:01:08,630 --> 00:01:06,880
does time really come to a standstill

31
00:01:10,830 --> 00:01:08,640
will we see a breakdown in general

32
00:01:13,750 --> 00:01:10,840
relativity in the environment of extreme

33
00:01:15,750 --> 00:01:13,760
gravity general relativity makes

34
00:01:18,310 --> 00:01:15,760
specific predictions about matter and

35
00:01:20,950 --> 00:01:18,320
energy close to a black hole

36
00:01:23,030 --> 00:01:20,960
if upon close scrutiny we see the

37
00:01:24,390 --> 00:01:23,040
slightest deviation between theory and

38
00:01:26,469 --> 00:01:24,400

observation

39
00:01:29,749 --> 00:01:26,479
we will understand limitations in

40
00:01:32,069 --> 00:01:29,759
einstein's equations

41
00:01:34,469 --> 00:01:32,079
two space missions will take us closer

42
00:01:36,390 --> 00:01:34,479
to a black hole event horizon than we've

43
00:01:38,950 --> 00:01:36,400
ever been

44
00:01:40,710 --> 00:01:38,960
lisa a joint nasa european mission now

45
00:01:43,190 --> 00:01:40,720
and formulation will listen for

46
00:01:44,870 --> 00:01:43,200
gravitational waves created by merging

47
00:01:47,429 --> 00:01:44,880
black holes

48
00:01:49,270 --> 00:01:47,439
now we're talking about opening a window

49
00:01:51,590 --> 00:01:49,280
that's not even

50
00:01:54,230 --> 00:01:51,600
based on electromagnetism it's a window

51
00:01:56,710 --> 00:01:54,240
that's based on gravitational radiation

52
00:01:58,870 --> 00:01:56,720
the gravity wave spectrum

53
00:02:00,630 --> 00:01:58,880
is kind of a new and really unexplored

54
00:02:04,630 --> 00:02:00,640
frontier

55
00:02:06,469 --> 00:02:04,640
no one's directly detected gravity waves

56
00:02:09,029 --> 00:02:06,479
as we start to open up this next

57
00:02:11,110 --> 00:02:09,039
frontier which i think many of us think

58
00:02:13,030 --> 00:02:11,120
of as the great frontier for 21st

59
00:02:14,550 --> 00:02:13,040
century astronomy

60
00:02:15,990 --> 00:02:14,560
i think we're going to learn about

61
00:02:17,270 --> 00:02:16,000
different things from different parts of

62
00:02:19,030 --> 00:02:17,280
that spectrum

63
00:02:21,190 --> 00:02:19,040

another mission will give us a closer

64
00:02:23,270 --> 00:02:21,200
look at black holes and probe the

65
00:02:26,150 --> 00:02:23,280
mystery of dark energy

66
00:02:28,309 --> 00:02:26,160
constellation x an x-ray observatory

67
00:02:29,910 --> 00:02:28,319
will make movies of the material falling

68
00:02:37,830 --> 00:02:29,920
into a black hole

69
00:02:42,790 --> 00:02:40,070
constellation x will let us watch how

70
00:02:45,670 --> 00:02:42,800
that matter approaches the event horizon

71
00:02:46,869 --> 00:02:45,680
and how from our perspective time creeps

72
00:02:49,589 --> 00:02:46,879
to a halt

73
00:02:52,070 --> 00:02:49,599
we'll be able to watch the final x-ray

74
00:02:54,710 --> 00:02:52,080
flicker of light as matter plunges into

75
00:02:56,790 --> 00:02:54,720
the black hole and disappears forever

76
00:02:58,710 --> 00:02:56,800
this is where we'll be able to probe the

77
00:03:00,869 --> 00:02:58,720
most extreme conditions of gravity that

78
00:03:03,110 --> 00:03:00,879
we know of and really put einstein's

79
00:03:12,869 --> 00:03:03,120
theories to the test

80
00:03:18,309 --> 00:03:16,229
in 1992 the nasa kobe mission discovered

81
00:03:20,630 --> 00:03:18,319
slight temperature fluctuations in the

82
00:03:21,670 --> 00:03:20,640
nearly uniform cosmic microwave

83
00:03:23,830 --> 00:03:21,680
background

84
00:03:25,990 --> 00:03:23,840
that's the blanket of light encompassing

85
00:03:27,589 --> 00:03:26,000
the universe that is the after glow of

86
00:03:30,710 --> 00:03:27,599
the big bang

87
00:03:32,710 --> 00:03:30,720
kobe's successor nasa's wmap mission

88
00:03:35,509 --> 00:03:32,720

produced this much higher resolution

89
00:03:37,589 --> 00:03:35,519
image of the cosmic microwave background

90
00:03:40,710 --> 00:03:37,599
becoming one of the most scientifically

91
00:03:43,270 --> 00:03:40,720
significant images of cosmology today

92
00:03:45,589 --> 00:03:43,280
we look at the wmap data

93
00:03:47,589 --> 00:03:45,599
much of what we see in the data has the

94
00:03:50,390 --> 00:03:47,599
imprint of the physical processes that

95
00:03:51,830 --> 00:03:50,400
took place about 300 000 years after the

96
00:03:53,830 --> 00:03:51,840
big bang

97
00:03:55,750 --> 00:03:53,840
the basic properties that we've inferred

98
00:03:58,390 --> 00:03:55,760
from this is that the geometry of the

99
00:04:00,710 --> 00:03:58,400
universe is flat or nearly flat we also

100
00:04:05,270 --> 00:04:00,720
know it's pretty old today we know it's

101
00:04:07,589 --> 00:04:05,280
about 13.6 13.7 billion years old and

102
00:04:09,350 --> 00:04:07,599
the stars formed about 100 million years

103
00:04:11,670 --> 00:04:09,360
after the big bang

104
00:04:13,910 --> 00:04:11,680
the information obtained by wmap and

105
00:04:15,990 --> 00:04:13,920
proposed missions will help distinguish

106
00:04:19,189 --> 00:04:16,000
between competing theories of what

107
00:04:21,749 --> 00:04:19,199
sparked inflation and the big bang

108
00:04:23,909 --> 00:04:21,759
einstein hoped to fold the quantum force

109
00:04:27,350 --> 00:04:23,919
of electromagnetism into general

110
00:04:28,950 --> 00:04:27,360
relativity and to find a unified theory

111
00:04:31,030 --> 00:04:28,960
much of what he could not answer and

112
00:04:33,110 --> 00:04:31,040
struggled with until the day he died

113
00:04:35,670 --> 00:04:33,120

remains unanswered today

114
00:04:38,230 --> 00:04:35,680
these questions about dark energy black

115
00:04:40,790 --> 00:04:38,240
holes the big bang and the nature of

116
00:04:43,510 --> 00:04:40,800
gravity have come to define the cutting

117
00:04:46,230 --> 00:04:43,520
edge

118
00:04:47,030 --> 00:04:46,240
the next revolution that i think could

119
00:04:49,189 --> 00:04:47,040
be

120
00:04:52,310 --> 00:04:49,199
in the not too distant future

121
00:04:54,870 --> 00:04:52,320
is to really learn what space and time

122
00:04:56,230 --> 00:04:54,880
actually are and i think as to others

123
00:04:58,310 --> 00:04:56,240
that we will learn that space and time

124
00:04:59,670 --> 00:04:58,320
are not fundamental there are more

125
00:05:03,189 --> 00:04:59,680
fundamental

126
00:05:05,110 --> 00:05:03,199
entities that make up space and time and

127
00:05:07,189 --> 00:05:05,120
when we can figure out what they are the

128
00:05:09,430 --> 00:05:07,199
atoms if you will of space and time

129
00:05:11,029 --> 00:05:09,440
themselves i think that will take our

130
00:05:13,350 --> 00:05:11,039
understanding of the universe to a

131
00:05:17,029 --> 00:05:13,360
completely new level and i think that

132
00:05:19,510 --> 00:05:17,039
discovery may be on the horizon

133
00:05:21,270 --> 00:05:19,520
like einstein's theories modern theories

134
00:05:22,790 --> 00:05:21,280
make fantastic predictions that seem

135
00:05:25,270 --> 00:05:22,800
hard to believe

136
00:05:26,710 --> 00:05:25,280
unseen dimensions and entire universes

137
00:05:29,590 --> 00:05:26,720
beyond our own

138
00:05:31,189 --> 00:05:29,600

we must find facts to confront and guide

139
00:05:33,430 --> 00:05:31,199
these new theories

140
00:05:35,749 --> 00:05:33,440
thus we follow matter to the very brink

141
00:05:37,830 --> 00:05:35,759
of black holes and detect particles of

142
00:05:38,870 --> 00:05:37,840
time left over from the beginning of the

143
00:05:40,390 --> 00:05:38,880
universe

144
00:05:42,469 --> 00:05:40,400
and we will use breakthrough

145
00:05:45,270 --> 00:05:42,479
technologies to see beyond the vision of