1
00:05:57,430 --> 00:05:55,120
we've found two correlations one is a

2
00:05:59,590 --> 00:05:57,440
correlation that more massive galaxies

3
00:06:02,530 --> 00:05:59,600
contain more massive black holes and the

4
00:06:04,210 --> 00:06:02,540
other is a correlation that galaxies in

5
00:06:30,470 --> 00:06:04,220
which the stars are moving faster

6
00:06:34,430 --> 00:06:32,840
what the results are telling us both of

7
00:06:35,930 --> 00:06:34,440
these correlations are telling us are

8
00:06:37,310 --> 00:06:35,940
screaming something important others

9
00:06:39,350 --> 00:06:37,320
they're telling us that there's a very

10
00:06:42,680 --> 00:06:39,360
close correlation very close connection

11
00:06:44,420 --> 00:06:42,690
between the time in the history of the

12
00:06:48,110 --> 00:06:44,430
black hole and the black hole got most

13
00:06:51,770 --> 00:06:48,120

of its mass and it's a process by which

14
00:06:53,000 --> 00:06:51,780
the galaxies form and we have suspected

15
00:06:54,890 --> 00:06:53,010
that there is such a correlation for a

16
00:06:57,470 --> 00:06:54,900
long time but it gets a lot more

17
00:07:25,280 --> 00:06:57,480
ironclad when the correlations that we

18
00:07:29,450 --> 00:07:27,950
for the past thirty years many people

19
00:07:30,950 --> 00:07:29,460
have been trying to understand quasars

20
00:07:32,930 --> 00:07:30,960
and they've built up a very complicated

21
00:07:34,850 --> 00:07:32,940
theoretical picture about what quasars

22
00:07:35,930 --> 00:07:34,860
are and on the other hand there have

23
00:07:37,490 --> 00:07:35,940
been other people who have been trying

24
00:07:39,500 --> 00:07:37,500
to understand galaxy formation and

25
00:07:41,450 --> 00:07:39,510
they've picked built up several pictures

26
00:07:42,950 --> 00:07:41,460
actually of how galaxies might form but

27
00:07:44,480 --> 00:07:42,960
the quasar in the galaxy formation

28
00:07:47,240 --> 00:07:44,490
pictures weren't very closely connected

29
00:07:49,160 --> 00:07:47,250
what our work has helped to do is cement

30
00:07:51,140 --> 00:07:49,170
the connection between the quasar and

31
00:07:53,050 --> 00:07:51,150
galaxy formation pictures and in doing

32
00:07:55,520 --> 00:07:53,060
so reduced the number of possibilities

33
00:08:23,490 --> 00:07:55,530
about galaxy formation that people are

34
00:08:27,150 --> 00:08:25,230
one of the missions of the hubble space

35
00:08:29,190 --> 00:08:27,160
telescope since the very beginning I

36
00:08:30,570 --> 00:08:29,200
think was always thought to be the

37
00:08:32,580 --> 00:08:30,580
search for supermassive black holes

38
00:08:34,320 --> 00:08:32,590

because what you need to do is be able

39
00:08:35,610 --> 00:08:34,330
to see very close to galaxy centers and

40
00:08:37,620 --> 00:08:35,620
getting outside the atmosphere is

41
00:08:39,529 --> 00:08:37,630
central to being able to do that so this

42
00:08:41,880 --> 00:08:39,539
problem has always been on our mind and

43
00:08:43,709 --> 00:08:41,890
similarly the properties of the

44
00:08:45,210 --> 00:08:43,719
spectrograph were designed in part to

45
00:08:46,950 --> 00:08:45,220
make it possible to do this kind of a

46
00:08:48,800 --> 00:08:46,960
search so both the Hubble Space

47
00:08:50,790 --> 00:08:48,810
Telescope and this spectrograph

48
00:08:52,470 --> 00:08:50,800
specifically are addressing a lot of

49
00:09:18,299 --> 00:08:52,480
problems but one of the central ones has

50
00:09:22,869 --> 00:09:21,069
this spectrum shows the other parts of

51
00:09:32,320 --> 00:09:22,879
the galaxy well in the inner parts of

52
00:09:36,410 --> 00:09:34,340
and the problem is that the surface

53
00:09:39,290 --> 00:09:36,420
brightness is bearing a lot galaxy

54
00:09:45,570 --> 00:09:39,300
that's bright so I can also display this

55
00:09:49,020 --> 00:09:47,250
and then you can begin to see that

56
00:09:51,000 --> 00:09:49,030
there's a zigzag in the spectral lines

57
00:09:53,790 --> 00:09:51,010
that's the signature of the black hole

58
00:09:55,440 --> 00:09:53,800
but you can't see it very well so if I

59
00:09:59,540 --> 00:09:55,450
take the surface brightness gradient and

60
00:10:01,740 --> 00:09:59,550
divide it out then I get this image now

61
00:10:03,420 --> 00:10:01,750
the surface brightness doesn't vary

62
00:10:05,940 --> 00:10:03,430
anymore because I've taken it out and

63
00:10:07,170 --> 00:10:05,950

all you see is the spectral lines and if

64
00:10:08,940 --> 00:10:07,180
you look at this you see there's a

65
00:10:11,670 --> 00:10:08,950
collection of very narrow lines here in

66
00:10:14,880 --> 00:10:11,680
here there night-sky absorption lines

67
00:10:16,530 --> 00:10:14,890
water in the Earth's atmosphere these

68
00:10:19,500 --> 00:10:16,540
are the lines that belong to the galaxy

69
00:10:22,110 --> 00:10:19,510
and you can see that these lines have a

70
00:10:25,710 --> 00:10:22,120
very big zigzagging in them and that's

71
00:10:28,320 --> 00:10:25,720
the Doppler shift the color at which the

72
00:10:30,930 --> 00:10:28,330
atoms in the star surfaces are absorbing

73
00:10:33,720 --> 00:10:30,940
light which is that color that color in

74
00:10:35,040 --> 00:10:33,730
that color but not these that color is

75
00:10:37,650 --> 00:10:35,050
being shifted it because the stars are

76
00:10:39,690 --> 00:10:37,660
moving so on one side it's shifted

77
00:10:41,730 --> 00:10:39,700
toward the red and the other side is

78
00:10:45,690 --> 00:10:41,740
shifted toward the blue that's because

79
00:10:46,980 --> 00:10:45,700
as you look at this galaxy this side is

80
00:10:50,130 --> 00:10:46,990
spinning away from you and the other

81
00:10:53,640 --> 00:10:50,140
side is spin towards so on one side the

82
00:10:55,350 --> 00:10:53,650
lights blue shifted and I'm the only

83
00:10:58,770 --> 00:10:55,360
side of the center the light red shifted

84
00:11:01,020 --> 00:10:58,780
like that and that's the signature of my

85
00:11:02,340 --> 00:11:01,030
home near the black hole the Stars have

86
00:11:05,010 --> 00:11:02,350
to move very fast because there's all

87
00:11:07,700 --> 00:11:05,020
this extra mass support and then I can

88
00:11:09,800 --> 00:11:07,710

take this spectrum and run it through a

89
00:11:12,690 --> 00:11:09,810
reduction program that calculates

90
00:11:14,340 --> 00:11:12,700
velocities right because all here here

91
00:11:17,370 --> 00:11:14,350
you see qualitatively what's going on

92
00:11:17,710 --> 00:11:17,380
but if I run it through the program that

93
00:11:23,769 --> 00:11:17,720
car

94
00:11:26,199 --> 00:11:23,779
velocities quantitative data

95
00:11:28,689 --> 00:11:26,209
this shows a quantitative version of

96
00:11:31,240 --> 00:11:28,699
this brightness as a function of color

97
00:11:34,329 --> 00:11:31,250
so it's a cut through this and this is a

98
00:11:36,490 --> 00:11:34,339
cut bad at large Radeon and these three

99
00:11:38,710 --> 00:11:36,500
spectral lines are these three spectral

100
00:11:41,230 --> 00:11:38,720
lines and you can see they're not as

101
00:11:43,329 --> 00:11:41,240
narrow as the night-sky lines but fairly

102
00:11:47,319 --> 00:11:43,339
narrow that's because the stars aren't

103
00:11:51,189 --> 00:11:49,509
this is a standard stuff so this is one

104
00:11:53,289 --> 00:11:51,199
single stock and you can see how much

105
00:11:54,729 --> 00:11:53,299
narrower the lines are the fact that the

106
00:12:00,400 --> 00:11:54,739
lines were broad and the other one means

107
00:12:03,639 --> 00:12:00,410
the stars are moving a little bit this

108
00:12:06,970 --> 00:12:03,649
is how the rotation velocity depends on

109
00:12:08,859 --> 00:12:06,980
position so rotation here rotation here

110
00:12:10,629 --> 00:12:08,869
rotation here and then as you get into

111
00:12:13,509 --> 00:12:10,639
the zigzag there's the big zigzag and

112
00:12:16,809 --> 00:12:13,519
rotation velocity and I can expand this

113
00:12:19,090 --> 00:12:16,819

up so you see it better this is just the

114
00:12:21,759 --> 00:12:19,100
very center you can see how very fast

115
00:12:23,769 --> 00:12:21,769
the center spinning on one side the

116
00:12:25,840 --> 00:12:23,779
Stars are going away from us at 150

117
00:12:27,879 --> 00:12:25,850
kilometres per second on the other side

118
00:12:29,679 --> 00:12:27,889
the Stars are coming toward us at 150

119
00:12:31,600 --> 00:12:29,689
kilometres per second because the centre

120
00:12:35,650 --> 00:12:31,610
spinning and at the very center of